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Khan, Faiza

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Evidence on Income Convergence: A Global Analysis

Faiza Azhar Khan

A thesis submitted for the degree of Doctor of Philosophy
University of Bath
Department of Economics

November 2012

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'A' to 'Z' of my Life, My 'A'(zhar) and 'Z'(awiyar)

Abstract

The theoretical debate on the question of the *poor becoming the rich*, or income convergence between countries, was mainly initiated with the introduction of the neoclassical growth model by Solow (1956) and Swan (1956). However, the convergence empirics are more recent and span just over a quarter of a century. This thesis aims at analyzing the multiple notions of income convergence for the world group of countries and within its various geographic and income clusters. The geographic clusters are Africa, Asia, Europe and Latin America & Caribbean, while, high, upper middle, lower middle and low income are the four income clusters in the study. Both β -convergence and σ -convergence are examined in their absolute and conditional forms. *Absolute β -convergence is defined as the convergence towards similar levels of per capita income across countries in the long run.* Therefore, absolute β -convergence involves a negative relationship between the growth rate of income and initial income while considering the cross-country steady state levels of income as constant. On the other hand, conditional β -convergence is defined as convergence towards respective steady state levels of income of countries. Conditional β -convergence takes into account the country specific geographic, structural and socio-economic variables and, thus, requires the equality of income growth rates rather than income levels. In other words, *conditional β -convergence entails a negative relationship between income growth and initial income after controlling for differences in steady state income levels of countries.* In contrast, *σ -convergence is defined as a reduction in income dispersion among countries over time.*

The absolute β -convergence is estimated by applying the non-linear least squares technique both with cross-sectional and panel data sets using the variables of GDP per capita and GDP per worker for the period 1950-2008. The estimation of a logarithmic trend regression for the income dispersion is the underlying methodology for analyzing σ -convergence. In addition, the dynamic panel data system GMM estimator is utilized for the study of conditional β -convergence. This estimation is based on five-yearly panel data spanning 1960-2008. The conditioning variables in the augmented Solow model include physical capital, population growth and human capital. Whereas, a Barro style income growth regression additionally includes the

fertility rate, life expectancy, institutional quality, a measure of democracy, trade openness, government consumption share, inflation rate and regional dummies. Further analysis of conditional β -convergence includes the study of the sources of convergence and the estimation of steady state levels of income for the sample countries. In addition conditional σ -convergence, also known as growth convergence, is examined utilizing the recently developed methodology by Phillips and Sul (2007a).

Results confirm no absolute β -convergence for the world countries and among its geographic and income categories, except for Europe, the high income and upper middle income countries. However, an important finding is the significant absolute β -convergence for the ‘world excluding the Sub Saharan African countries’. Because of contradictory results, the conclusions on σ -convergence are dependent on the two measures of dispersion utilized in the study. The analyses suggest that the extensively cited relationship between β and σ convergence is only pertinent when the standard deviation of log income is the measure of σ -convergence; implying that σ -convergence is plausible in the absence of β -convergence. Contrary to the infrequent evidence for absolute β -convergence in the sample categories, conditional β -convergence is confirmed for the world sample and for each of its geographic and income categories for both the augmented Solow model and Barro style income growth regressions, with the exception of low income countries. Europe, Latin America and Asia have higher rates of convergence compared to the African continent, in which GDP per worker is converging at a higher speed than GDP per capita, because of higher dependency ratios. Moreover, convergence rates for the world sample are lower than those for various regions. Finally, in the growth convergence analysis based on a time-varying factor model, Europe again has shown more convergence. But, the African, Asian and Latin American regions are divided into further convergence clubs with 5, 2 and 5 clubs respectively. Similarly, there is no evidence of growth convergence for the world sample, but for 6 global clubs comprising varying numbers of countries.

Some of the original contributions of the thesis are, firstly the re-consideration of the relationship between absolute β and σ convergence. Secondly, varying rates of conditional β -convergence for GDP per worker and GDP per capita

are found. In this context, the presence or absence of conditional β -convergence in the workers to population ratio has a key role; therefore, these results indicate that the demographic structure of countries and the record of population growth have played an important role in the income convergence of countries. Thirdly, a further analysis of conditional β -convergence for low income countries shows institutional quality to be relatively more important than initial human capital for income convergence. Specifically at low initial levels of development, institutional quality has a greater role in income growth and convergence.

List of Abbreviations

ADF	Augmented Dickey Fuller
BACE	Bayesian Averaging of Classical Estimates
BMA	Bayesian model averaging
CART	Classification and regression tree
EBA	Extreme bound analysis
ECOWAS	Economic community of West African States
EFW	Economic freedom of the world
ESTAR-ADF	Exponential smooth autoregressive augmented Dickey-Fuller
G-K	Geary Khamis
GMM	Generalized methods of moments
GNI	Gross national income
GSP	Gross state product
H-D	Harrod-Domar
I\$	International dollars
ICT	Information communications Technology
ILO	International Labour Organization
IMF	International Monetary Fund
ISI	Import Substitution industrialization
IV	Instrumental variable
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
LAE	Least absolute error
LM	Lagrange multiplier
LMI	Lower middle income
LSDV	Least squares dummy variable
MADF	Multivariate augmented Dickey-Fuller
MENA	Middle East and North Africa
MERCOSUR	Spanish name for Southern common market
NGM	Neoclassical growth model
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organization for Economic Cooperation and Development

OLS	Ordinary least squares
OPEC	Organization of the Petroleum Exporting Countries
PCSE	Panel corrected standard errors
PMGE	Pooled mean group estimator
PPP	Purchasing power parity
PWT	Penn world table
R&D	Research and development
RWLS	Reweighted least squares
SSA	Sub-Saharan Africa
SURADF	Seemingly unrelated regressions augmented Dickey–Fuller
TFP	Total factor productivity
USSR	Union of Soviet Socialist Republics
WENAO	Western European, North American and Oceania
WWII	World War II

Chapter 1

INTRODUCTION

1.1. INTRODUCTION AND RATIONALE OF STUDY

One of the key issues of research in the area of economic growth and development has been the *convergence hypothesis* or the debate on the ‘*poor becoming the rich*’. Alternatively termed as ‘*catching up*’ or ‘*economic convergence*’ in the literature, the concept of income convergence, in simple words, entails a reduction in per capita income gaps across countries or regions. Alternatively and more formally, it refers to the faster growth of poor countries relative to that of rich countries as a result of which per capita income levels of all countries come closer. *This convergence in per capita income levels of countries is termed as unconditional or absolute β convergence.* In contrast, *a negative relationship between income growth and initial income after controlling for country-specific factors is known as conditional β -convergence.* Alternative to β -convergence is the concept of σ -convergence which is defined as the reduced income dispersion of countries over certain time period.

The subject of income convergence has been focus of some of the theoretical and empirical literature for a long time and has developed in various forms and applications. In an informal approach, a simple comparison of per capita incomes of world countries/regions can yield useful information on income gaps of countries/regions. While, more formally and importantly, there are various methodological formulations of convergence hypothesis based on a variety of techniques that have been utilized to empirically evaluate this hypothesis.

Per capita incomes of world countries have always been changing over time. Historians and economists have been engaged in comparative analyses of income levels of world countries once the availability of the required data became available.¹ A closer look at Maddison’s historical data indicates that the minimum and

¹ In this context, a very useful source of information is the Maddison’s historical database on per capita income levels of world countries from 1000 AD to 2008 AD.

maximum per capita income values across world countries in 1000AD were \$400 and \$650 respectively.² One thousand years later, these minimum and maximum income levels stood at \$409 and \$28,467 respectively; therefore, indicating some sort of information on relative income levels across world countries. However, over these years there have been many changes in the geographic map of the world and the actual number of countries on the world map has changed. More importantly, number of countries with the data availability has drastically increased since 1950. Therefore, these income values are not directly comparable over 1000 years, but they can be compared over a sixty years time period which can be a sufficiently long period for a formal study of income convergence.

It is pertinent to analyze the data of per capita income of world countries for the last sixty years to evaluate their comparative performance in the context of income convergence. This time period encompass years of reconstruction in the developed world after world wars, together with independence, from colonialism, for a large number of developing countries. From the perspective of the overall development of world countries, a specific focus should be on the study of inter-country/inter-region differences, in terms of both their spatial and temporal dynamics. Because, a comprehensive study of income convergence can help identify the regional disparities, which are an obstacle in achieving the global development.

1.2. BACKGROUND LITERATURE

The formal theoretical debate on the subject of income convergence initiated with the introduction of neoclassical growth model (NGM) by Solow (1956) and Swan (1956). However, two economists, David Hume and Josiah Tucker, discussed the issue of *catching-up* of poor countries, as early as, in 18th century [Elmslie (1995)]. In Hume's point of view, convergence of a poor country to the rich is plausible because of trade and technology transfer and may also be natural to an extent [Hume (1742), cited in Elmslie (1995)]. In contrast, Tucker favoured the possibility of

²Historical Statistics of the World Economy: 1-2008AD, available at www.ggd.net/maddison/Historical.../horizontal-file_02-2010.xls.

income divergence while taking into account the knowledge gap between the rich and poor countries as continuous [Tucker (1776), cited in Elmslie (1995)]. More recently, Veblen (1915) emphasized advantages of *follower* countries in a development process, which, therefore, implies the possibility of convergence for poor countries.

Besides these infrequent and brief thoughts on income convergence, a formal discussion and formulation of the convergence hypothesis, and, specifically, within the framework of growth model, was actually extended by Solow (1956) and Swan (1956). Thereafter, the convergence hypothesis is an important component of the research work on economic growth and has been discussed in the literature for more than half a century now. Because of the non-availability of longer data-sets in the earlier periods, the convergence empirics span a relatively shorter time-period of a quarter of a century and originated with the contributions by Abramovitz (1986) and Baumol (1986). However, these initial empirical studies were independent of the framework of the NGM. Subsequently, Barro and Sala-i-Martin (1990) derived the convergence equation from the NGM and the catching-up hypothesis was named as ' β -convergence' which, due to the assumption of cross-country constant steady states, is now referred to as '*absolute or unconditional β -convergence*' [Barro and Sala-i-Martin (2004)]. Later on, these cross-country differences in steady states were incorporated in the analysis of convergence and this notion is known as '*conditional β -convergence*' [Sala-i-Martin (1996a)].

The regression analysis pertaining to unconditional β -convergence was criticized by Friedman (1992). Cross-sectional estimation of the convergence equation was referred as the *regression fallacy*, instead of being an indication for the poor becoming the rich because they are based on the averages for the entire time-period [Friedman (1992)]. As an alternative to β -convergence, Friedman suggested that the temporal study of the cross-sectional dispersion of income is more plausible. However, even prior to Friedman's recommendation, the trend in the cross-country income dispersion (i.e. what was called ' σ -convergence') was analyzed in the convergence empirics together with the β -convergence. Moreover, the equation for σ -convergence was derived from that of the β -convergence and the latter is rendered as a necessary but not sufficient condition for the former [Barro and Sala-i-Martin

(1990; 1992)]. Various econometric methodologies have been utilized to analyze these concepts using both the cross-country and intra-country regional data-sets [see chapter 3 on review of literature].

In recent years, in the analysis of convergence empirics, methodological issues, instead of the conclusions on income convergence, are the focus of many studies [see review of literature in chapter 3]. In an evaluation of the econometrics of convergence, Durlauf et al. (2009) stated that *“our belief is that progress is most likely if the economic content of specific versions of convergence is placed at the center of the analysis, so that statistical sophistication is not an end in itself”*. In this context, one of the recent studies with the emphasis being convergence implications is by Rodrik (2011), who has studied the cross-country absolute β -convergence among industries.

1.3. OBJECTIVES OF THE STUDY

This study aims at furnishing a comprehensive empirical analysis of the convergence hypothesis for world countries and also for its various geographic and income categories over the time-span of last fifty to sixty years. With its key focus on cross-country convergence evidence and the implications, this study attempts to analyze the subject in its various formulations, both old and new. Up-to-date evidence on absolute β -convergence, conditional β -convergence, absolute σ -convergence and conditional σ -convergence is furnished utilizing the latest econometric techniques. Both absolute β -convergence and conditional β -convergence are analyzed using GDP per worker and GDP per capita. The augmented Solow model and the Barro income growth regression are two variants of model for the analysis of conditional β -convergence. In addition, sources of convergence will be analyzed by separately estimating conditional β -convergence for physical capital to labour ratio, human capital per worker and total factor productivity (TFP). Since conditional β -convergence implies convergence towards respective steady states of countries; a further analysis on the topic will look at the behaviour of steady states across countries over the study period. Together with the overall sample, comparative analyses of various geographic regions and income clusters utilizing the similar techniques and datasets will contribute useful insights into the subject, specifically,

regarding *club convergence*. Finally, another significant focus of this study is to analyze the link between various notions of convergence for definite conclusions on the topic.

1.4. OUTLINE OF THESIS

Considering the relationship between theories of economic growth and income convergence, chapter 2 discusses various growth theories and their respective conclusions on the subject. Alongside the theory, a simple descriptive comparative analysis of data on per capita incomes of world countries and regions spanning the period 1950-2008 is also presented, in this chapter, for a preliminary examination of catching up among countries. One of the highlights of this chapter is the information on respective income categories of each sample country in 1950 and 2008, to directly observe whether a country has been able to move from a lower category to the higher one (*poor becoming the rich*) in these sixty years.

Any empirical study is incomplete without the discussion of the literature on the relevant subject to develop a plausible background for the analysis. Like many other topics, there are numerous studies on income convergence entailing various notions and econometric techniques. A review of the literature on income convergence is presented in chapter 3 which includes cross-country and inter-country studies on absolute and conditional β -convergence, absolute σ -convergence, club convergence, and time-series convergence. This comprehensive literature review is followed by four empirical chapters on the analysis of income convergence with distinct concepts and methodologies. Initially, absolute β and σ convergence are analyzed in chapter 4 by utilizing the non-linear least squares estimation technique and simple trend regressions respectively. Absolute β -convergence estimations are based on cross-sectional and panel data with both GDP per capita and GDP per worker. While, two measures of dispersion, namely, the standard deviation of log income and the coefficient of variation of income are used in analyzing σ -convergence. Further discussions on the relationship between β and two measures of σ convergence are an important part of chapter 4.

The weak evidence of absolute convergence among world countries and its regions found in chapter 4 necessitates an analysis of conditional β -convergence among these samples. This constitutes chapter 5. The widely utilized frameworks of the augmented Solow model and Barro regression are applied for this purpose. The analysis based on the former includes two output measures, namely, GDP per worker and the GDP per capita. The dynamic panel system GMM method is used for all the estimations in chapter 5. In contrast to the results on absolute β -convergence, there is substantial evidence for conditional β -convergence for various categories except for the low income countries. Therefore, further analysis of conditional β -convergence for low income group with a particular focus on role of initial human capital and/or institutional quality is presented in chapter 6. This chapter also comprises an analysis of sources of the convergence of GDP per worker, namely, physical capital per worker, human capital per worker and TFP. Besides, conditional β -convergence is also examined for the workers to population ratio to evaluate the role of demographic structure in income convergence. Furthermore, the behaviour of the distribution of steady states within each sample is illustrated in chapter 6 for further insights on conditional convergence.

The whole analysis on β -convergence is based on the assumption of constancy of technological growth and the speed of convergence across countries. However, Phillips and Sul (2007a) have developed an approach of income convergence, termed '*growth convergence or conditional σ -convergence*', taking into account varying speeds of convergence and technological growth rates. The approach also tests for the possibility of convergence clubs among countries and identifies such clubs. Chapter 7 in this thesis is based on this recent approach of income convergence and tests for the growth convergence and convergence clubs in all of the aforementioned samples. Finally, after having presented comprehensive empirical analysis on four different approaches of income convergence, each with nine samples, and mostly with two output variables, the study concludes in chapter 8 with further discussion on pertinent findings.

1.5. CONTRIBUTION TO LITERATURE

In part the thesis adds to the existing literature on cross-country income convergence by filling some of its gaps. A comprehensive analysis on various notions of income convergence for multiple categories may offer a better comparison when using a similar methodological approach than when using diverse data sources and methodologies pertaining to different studies by different authors. Each type of convergence is analyzed for approximately nine samples, namely, the full world, Asia, Africa, Europe, Latin America & Caribbean, high income, upper middle income, lower middle income and low income. Some of the unique aspects of this study on income convergence are: (i) comparison of two measures of absolute σ -convergence and their inter-relationship with absolute β -convergence utilizing the real world data, (ii) analysis of conditional β -convergence with both GDP per worker and GDP per capita utilizing the augmented Solow model, (iii) a comparative study of conditional income convergence using the frameworks of the augmented Solow model and the Barro growth regression, (iv) analysis of income convergence for low income countries with a specific focus on quality of institutions and the initial level of the human capital, (v) analysis of sources of convergence and steady states in a panel framework and (vi) analysis of growth convergence and convergence clubs for Asia, Africa and Latin America & Caribbean.

Two of the major findings of this study are the evidence of absolute β -convergence for the world sample excluding sub Saharan African (SSA) and the revision of the relationship between β and σ convergence. This analysis has shown that the relationship between β and σ convergence is specific to standard deviation of log income being the measure of σ -convergence and not otherwise. Thirdly, rates of conditional β -convergence with GDP per worker are not similar to those of GDP per capita and dynamics regarding demographic variables have a major role in explaining this difference between rates of conditional convergence. Moreover, institutional quality and not the initial human capital is the key in explaining the income convergence of the low income countries.

Further discussions on these findings together with some other results will be presented in the following chapters.

Chapter 2.

THEORETICAL AND HISTORICAL PERSPECTIVES ON ECONOMIC GROWTH

2.1. INTRODUCTION

Economic growth is an essential though not the only component for the development of a country or region having its imperatives both in the short and the long run. Typically, the fundamental debate on economic growth is concerned with the long run because short run fluctuations in output of the economy are widely considered a part of business cycle. A parallel debate in development economics, supplementing the literature on long run economic growth, has been the inter-country/inter-region per capita income differences in terms of both their spatial and temporal dynamics.

The convergence hypothesis is the core of a great deal of research work on economic growth and has been debated in the literature for more than half a century now. Beginning with the neoclassical growth model (NGM) given by Solow (1956) and Swan (1956), the simple concept of convergence has been evolving along a continuum of multiple theoretical modifications. The understanding and application of the latter entails a prior knowledge of both the theory of economic growth and the actual trend of long run per capita income growth in the world.

This chapter attempts to present a review of some of the theoretical perspectives on economic growth alongside a brief look at historical trends in per capita income of countries across the world. Keeping in perspective the association of this topic with the theory of economic growth, part 2.2 briefly sheds some light on different models of economic growth together with reflecting on the theoretical underpinnings of the basic concept of convergence. The long-run trends in per capita income and its growth rates are discussed in the third part while, further analysis on the current income classification of previously lower middle and low income

countries will be discussed in the fourth part. Finally, conclusions and research questions for further empirical analysis are presented in the fifth part.

2.2. THEORY OF ECONOMIC GROWTH: A CHRONICLE

The theory of economic growth predates even Classical economics. The significance of the former, however, lies in researches carried out, providing diverse and at times, controversial views on various determinants of economic growth. Furthermore, processes describing the interplay of these determinants and their short and long run economic implications have been widely subject to modifications. A comprehensive and thorough discussion on the old and modern theories of economic growth therefore necessitates a chronological organization of this part into three distinct sections. Section 2.2.1 and 2.2.2 present theories of economic growth prior to the NGM and the NGM respectively, while endogenous growth theory is discussed in the third Section 2.2.3.

2.2.1. Pioneering Theories of Economic Growth

Numerous determinants of economic growth have been identified by economists at various times in history and some of them have also been incorporated in the modern theory of economic growth. To begin with, the mercantilists, while emphasizing production, exports of goods and price management, favored the interest of producers at the expense of consumers and the working population on the premise that consumption was not good for the economic growth [Sayre (2010)]. In contrast, Smith (1776) highlighted the role of consumption as an essential ingredient of economic growth. More importantly, he accorded the primary role being played by the division of labor in view of the fact that specialization, higher labor productivity, higher wages and hence higher consumption all are consequential to this fundamental economic activity. Smith (1776) further maintained that, initiated by the division of labor, consumption is the only and eventual purpose of production; guaranteeing smooth continuation of the cycle of economic expansion in the effectual presence of forces of competition and free market.

Following Smith (1776), other Classical economists endorsed the notion of invisible hand as a prerequisite for economic expansion. Malthus (1798), however, doubted Smith's view of growth being sourced out of the interplay of division of labor and consumption. His argument rested on diminishing marginal returns following from high population growth and fixed quantities of land. Ricardo (1817) extended the principle of diminishing marginal returns to other inputs as well and also underscored the negative impact of technological progress on the wages of labor in agricultural sector.³ Another of his major contributions is in highlighting the significance of foreign trade for economic growth. Subsequently, important contributions continued to be made in the early theory of economic growth up until about the middle of last century [Young (1928); Ramsey (1928); Schumpeter (1934); Knight (1944)].

Defying the argument of diminishing marginal returns, with the justification of extended division of labor owing to internal and, specifically, external economies of scale, Young (1928) discussed the possibility of increasing returns to capital in production. In his opinion, increasing returns, derived from externalities of capital accumulation, can guarantee sustainable economic growth even in the absence of labor force growth and technological progress. Parallel in time, but opposite in nature, was the work of Ramsey (1928), whose focus was the realm of consumption. Contrary to the sphere of production addressed by Young (1928), Ramsey (1928) devised an optimal household consumption model extended over successive time periods. His most significant contribution is the concept of endogenous savings derived from a household utility maximization framework.

The topic of growth theory was explored in time by Schumpeter (1934) who, while according entrepreneurship a pivotal role, came up with an entirely different perspective. He argued entrepreneurs, through their investment on research and development (R&D), are a source of innovation and thus the agents for technical change and an ensuing long-term economic growth in an economy. Adopting a similar focus, Knight (1944) has underlined the significance of new investment as a

³ Technological progress in the form of labor saving machinery causes a fall in consumption through reduction in employment.

stimulus for technical knowhow, proliferating on its own and, resultantly, inducing a permanent positive impact on the economy.⁴

Majority of the early growth work was developed against the backdrop of a competitive framework of a capitalist economy. However, following the Keynesian tradition, Harrod (1939) and Domar (1946) separately developed models of economic growth with similar theoretical underpinnings. Together termed as Harrod-Domar (H-D) model, their work is a forerunner to NGM that has signified the role of savings and marginal productivity of capital in determining economic growth. The H-D model takes the following Leontief form:

$$Y_t = \min\{bL_t, vK_t\} \quad (2.1)$$

Where v is the average/marginal product of capital and b is the average/marginal product of labor. The specific form of the model used in the literature is:

$$Y_t = vK_t \quad (2.2)$$

The growth rate of output in this model can be written as:

$$G_y = \dot{Y}(t) / Y(t) = sv = s/c \quad (2.3)$$

In the above equation G_y is the growth rate of the output defined as the over-time change in output, $\dot{Y}(t)$, divided by the actual output, $Y(t)$. According to the H-D model, economic growth is equivalent to the ratio of the saving rate, s , and the capital output ratio, c .

Notwithstanding the strength of its theoretical underpinnings, the assumptions; including a Leontief type technology and constant returns to scale, ensued widespread criticism [Sato (1964)], hence the subsequent development of the NGM.

⁴ New investment is defined as an investment additional to the size required for maintaining the existing level of capital stock in an economy.

2.2.2. Neoclassical Models of Economic Growth

The NGM given by Solow (1956) and Swan (1956) is a simple and dynamic framework for analyzing long-run economic growth. Besides already existing capital stock, the NGM augmented the H-D model with supplementary factors namely labor and time variant technology while assuming diminishing returns to scale for both labor and capital.⁵ Keeping in perspective the criticism on fixed proportions functional form in H-D model, the Cobb-Douglas form of production function, within a closed economy framework, with constant returns to scale was specified for this model. The production function in the Solow growth model takes the form:

$$Y(t) = [K(t)]^\alpha [A(t)L(t)]^{1-\alpha} \quad (2.4)$$

And its intensive form (per effective labor form, found by dividing it by AL) can be written as:

$$y(t) = (k(t))^\alpha. \quad (2.5)$$

The growth rate of capital ($k(t) = \frac{K(t)}{A(t)L(t)}$) is equal to:

$$\frac{\dot{k}(t)}{k(t)} = s(k(t))^{-(1-\alpha)} - (n + g + \delta) \quad (2.6)$$

And ensuing output growth is given by⁶:

$$\frac{\dot{y}(t)}{y(t)} = \alpha \frac{\dot{k}(t)}{k(t)}. \quad (2.7)$$

In the growth equation for capital per effective labor (2.6), s is the saving rate while n, g, δ represent population growth, technological growth and the depreciation rate respectively. The saving rate and population growth rate are both considered exogenous with the supposition that, in the steady state, neither of the two variables can have growth effects on endogenous variables of the model namely, the output

⁵ In Solow model, labor and technology are introduced in multiplicative form, thus labor is termed as effective labor and technology is referred as labor augmenting or *Harrod-Neutral*.

⁶ For detailed derivations of these equations, see Chapter 4, section 4.2.1.

and the consumption.⁷ Furthermore, NGM designated technological progress as the only variable determining the long run growth of economy in the steady state, and that, too, is assumed exogenous. The exogenous treatment of most strategic variable of the model appears to render public policy irrelevant in terms of its impact on the economic growth of a country [Barro and Sala-i-Martin (2004)].

The assumption of diminishing marginal product of inputs explicated through the *Inada conditions* set the foundations for the concept of convergence. The Inada conditions illustrate the shape of production function for the NGM by affirming that output is strictly increasing in inputs but its derivative is decreasing [Solow (1956)]. Solow (1956) further argued that countries with lower level of initial per capita gross domestic product (GDP) grow faster in their per capita GDP, hence depicting a negative relationship of per capita growth with the initial level of real per capita GDP. The concept that poor economies grow faster than that of the rich in per capita income is termed as the ' β -convergence'. However, comparable to the β -convergence in its implication, and indebted to its empirical literature for its origin, is the notion of σ -convergence which measures the dispersion in per capita income between a group of countries or regions [Barro and Sala-i-Martin (1990)]. Researchers have provided empirical analysis for both of the convergence approaches using diverse data and methodologies which will be the topic of the next chapter. For now the evolution of growth theory is continued with the discussion on further developments in NGM.

Cass (1965) and Koopmans (1965) modified the Solow model by altering the status of a previously exogenous variable, the savings rate, to be endogenous. Utilizing their infinite horizon model of consumer behavior, the authors ruled out the possibility of inefficient savings predicted in the Solow model.⁸ However, a further assumption of relative risk aversion being constant in an inter-temporal elasticity of substitution utility function is incorporated as a prerequisite for the existence of a steady state. The household's total utility function in their model takes the form:

⁷In this model steady state equilibrium is a point where growth rate of capital stock per worker and hence, output per worker and consumption per worker remain constant.

⁸Their model of consumer behavior was a revision of the work by Ramsey (1928), thus is also referred as Ramsey-Cass-Koopmans model of optimal growth.

$$U = \int e^{-\rho t} u(C(t)) \frac{L(t)}{H} dt \quad (2.8)$$

Consumption by each member of the household at time t is given by $C(t)$ and total number of members in a household is shown by $\frac{L(t)}{H}$. Because, $L(t)$ denotes total population and H indicates number of households in the economy. while, ' ρ ' is the discount rate. The instantaneous utility is:

$$u(C(t)) = \frac{C(t)^{1-\theta}}{1-\theta}. \quad (2.9)$$

θ is the coefficient of relative risk aversion defined as $-\frac{Cu''(C)}{u'(C)}$.

Nevertheless, analogous treatment of production side maintained broader conclusions of the model, including the convergence hypothesis, unchanged [Barro and Martin (2004)].

Although, the NGM warrants to be commended for its pioneering analytical rigor, the model invited criticism on its certain aspects. The critics, specifically, targeted both the exogenous treatment of technological change and the assumption of constant returns to scale in production. Thus, it is indeed the criticism of the NGM that inspired further research on the theory of economic growth discussed in the following section.

2.2.3. Endogenous Growth Theories

Long-run economic growth as a subject lost its significance in 1960s for a duration of the prevalence of Keynesian economics when short run economic fluctuations and theory of business cycle were in focus [Barro and Martin (2004)]. However, the recession in 1970s, and the consequential move away from the Keynesian economics, changed the direction of public policy in favor of neo-liberalist economics [Herrera (2006)]. Indeed, during the time period of 1980s, the question of long run economic growth restored its prominence with new dynamism [Herrera (2006)]. Specifically with the advent of endogenous growth theory, contributed by

Romer (1986) and Lucas (1988), and augmented by Romer (1990) through its comprehensive analytical formulations.

Romer (1986) envisaged a dynamic growth process involving many implications which did not conform to the suggestions of the NGM. Proscribing the likelihood of exogenous technical change, his model introduced the phenomenon as an endogenous variable ensuing from accumulation and spillovers of knowledge. More importantly, owing to the emphasis on investment externalities and increasing marginal product of knowledge, Romer (1986) also pioneered the concept of increasing returns to scale in production; hence allowing a continuous and rising steady state per capita growth path for a country.⁹ The production function can be written as:

$$Y = K^{a+x} L^b (a+x=1, \Rightarrow a+x+b > 1) \quad (2.10)$$

Where x denotes the externalities ensuring constant returns to physical capital.

Alternatively, endogenous growth theory ascribed to Lucas (1988) was based on the incorporation of human capital (H) in the growth model as one of the variables expected to help yield increasing returns. A major source of the latter is to be recognized, as spillover effects associated with both learning by doing, while having access to technological artifacts of capital stock, and investment in education and training.¹⁰ Production function for this particular endogenous growth model is:

$$Y = K^a L^b H^c (a+c=1, \Rightarrow a+b+c > 1) \quad (2.11)$$

In this production function, combined returns to physical and human capital are assumed constant. Lucas's (1988) growth theory, like that of Romer (1986), is also different from the NGM in its suggestion to ascribe a significant role to policy measures for the long run economic growth. Despite these parallels, these two

⁹ Indeed, the possibility of increasing returns to scale in production, owing to learning by doing, non-rival characteristic of knowledge and immediate process of technological diffusion, had already been initiated by Arrow (1962) and Sheshinski (1965). However, the descriptive nature of their work not only lacked model formulation orientation for competitive equilibrium in the presence of externalities, the limitations of the studies; such as strict dependence of per capita income growth on labour force growth, also rendered further analysis unfeasible [see, Romer (1990)].

¹⁰ The significance of human capital had also been highlighted earlier by Uzawa (1965), in the discussion on the relationship between education and economic growth.

models differ regarding their handling of a vital variable in the growth model, technology. Owing to investment externalities, Romer's (1986) model envisaged technology as a public good and a spontaneous outcome of other related economic decisions [Martin and Sunley (1998)]. However, technological development in Lucas's (1988) model is considered as the result of purposeful decisions of individual economic agents for investment in education and research to acquire human capital [Martin and Sunley (1998)]. As far as the context of this study is involved, the distinguishing feature of both of these endogenous growth theories is to be underscored in terms of the negation of convergence possibility between per capita incomes of countries, because of the existence of multiple long run growth paths [Romer (1994)]. This very important postulation largely results from the consideration of increasing returns to scale and differences in technological capabilities of countries [Romer (1994)].

Furthermore, another set of endogenous technology models is developed in the backdrop of Schumpeter's growth theory. He viewed entrepreneurship as a vital source for innovations and technological abilities and consequently for economic growth. These Schumpeterian endogenous innovation growth theories owed technological development of a country to the innovations accomplished through R&D undertaken by oligopolistic firms in expectations of higher profits [Grossman and Helpman (1991)]. Subsequently, technological transfer, diffusion and imitation cause the overall expansion in the economy. The production function underlying this model is:

$$Y = CK^a L^b D^d \quad (2.12)$$

'C' is a constant and 'D' is an index of innovative progress [Grossman and Helpman (1991); Aghion and Howitt (1992)].

Implications of the later endogenous growth models regarding cross-country income convergence are contrary to those of the earlier ones. Owing to technological transfers, the later endogenous growth theories inclusive of endogenous innovation models do not entirely rule out the possibility of income convergence among the countries e.g. Barro and Sala-i-Martin (1997) and Howitt (2000). Barro and Sala-i-Martin (1997) have formulized a model of economic growth integrating endogenous

technology with that of conditional convergence. Their model was based on inventions and imitations of technology by two distinct types of countries in the world. These were termed as the leaders and the followers respectively and their uniqueness of being the technological leader or follower was also determined endogenously.

Howitt (2000) has formulated an open economy extension of the Schumpeterian growth model explaining cross-country income differences while incorporating R&D and technology transfer. Besides the differences in capital stock per worker, as asserted by NGM, productivity differences were underscored as an equally important source of income differentials. In this derived model, growth convergence is only realized by countries with positive amount of R&D and not otherwise. Moreover, value of the coefficient on capital stock is lower in Schumpeter's model as compared to that of NGM, thus signifying a greater consistency of Schumpeter's model with the real world data.

Considering the topic of endogenous growth and convergence, Ortigueira and Santos (1997) has studied determinants of the speed of convergence in the endogenous growth model with physical and human capital. Convergence in growth rates are considered, while maintaining the cross-country differences in income levels. According to the findings of study, speed of convergence is positively caused by the productivity of human capital technology while the share of physical capital has an opposite effect. Moreover, contrary to the conclusions of NGM, this particular model corroborated no relationship between the preference parameter and the rate of convergence.

A further discussion on the phenomenon of income convergence within endogenous growth theories will be presented in the following chapters.

2.3. PER CAPITA INCOME AND GROWTH: A CHRONICLE

“One of the most difficult and intriguing tasks of a theory of economic growth is to combine both the disruptive and the integrative, the

qualitatively changing and the quantitatively steady, aspects of the process". [Kuznets (1965):23]

This part is an attempt to furnish a descriptive analysis of long-run income growth in a comparative perspective involving both temporal and cross-sectional dimensions. The whole discussion is divided into two sections; section 2.3.1 focuses on central tendency and the spread of per capita GDP levels across various regions of the world in the initial and terminal periods of the data. A historical overview on the growth rates of the per capita income and the population across these regions will be presented in the second section, 2.3.2.

2.3.1. Cross-sectional Account of the Per Capita Income Levels

Adhering to the existing convention of studies on the subject, real GDP per capita at PPP is utilized as a reference variable for income and it is based on the international Geary-Khamis (G-K) dollar with the base year 1990. The G-K dollar is equivalent to the US dollar in purchasing power and simultaneously takes into account the purchasing power parity and international average prices of commodities [Geary (1958); Khamis (1972)]. The data for real per capita GDP at PPP is accessed from Maddison's database which is a wide-ranging database on GDP, per capita GDP and population for individual countries as well as a variety of regions across the time periods 1 AD to 2008 AD. However, owing to the missing observations and more importantly to the attempt for a comprehensive analysis involving broad cross-section of countries over regular annual time frequency, the aforementioned data reduced to 137 countries spanning from 1950 to 2008.

Keeping in perspective the long run income growth and its convergence, Table 2.1 presents a historical outlook on the per capita GDP of the world and for the geographic and income categories of the world sample. This geographic classification broadly comprises different continents, namely Asia, Africa, Europe and Latin America & Caribbean region. The category of '*western offshoots*', as was coined in the Maddison's dataset, includes continents of North America and Australia. Because of Mexico being in Latin American group, the former category comprises Australia, Canada, New Zealand and the USA. Furthermore, in the context

Table 2.1. Comparison of Real Per GDP Per Capita (PPP): A Historical Retrospective									
Time period	1950				2008				1950-2008
Region/Value	Median	Highest (H)	Lowest (L)	H as ratio of L	Median	Highest	Lowest	H as ratio of L	Average Growth (%)
<i>Geographic Classification</i>									
World	1,259	30,387	289	105	3,987	31,704	249	127	2.2
Asia	960	30,387	396	77	5,702	31,704	869	37	3.6
Africa	711	3,108	289	11	1,233	22,049	249	88	1.2
Europe	3,706	9,064	1,001	9	22,223	28,500	4,149	7	2.8
Latin America & the Caribbean	1,963	7,462	1,027	7	5,388	21,314	686	31	1.8
Western Offshoots	7,934	9,561	7,291	1.3	25,284	31,178	18,653	2	2.1
<i>Income Classification</i>									
High income	7,959	30,387	6,769	4	24,076	31,178	10,596	3	2.0
Upper middle income	4,253	5,996	3,453	2	22,223	28,500	9,893	3	2.6
Lower middle income	2,189	3,108	1,863	2	8,032	31,704	2,959	11	2.9
Low income	810	1,720	289	6	1,672	22,049	249	88	3.2
Source: <i>Author's calculations based on Maddison's data</i>									
This Table reports the median, highest and lowest values of real per capita income along with the average growth rates. Growth shows the average annual growth rate of real GDP per capita over the period 1950-2008. The per capita GDP is measured in the Geary Khamis dollars with the base year of 1990. The category of Western offshoots comprises of Australia, Canada, New Zealand and USA. The four income groupings (in line with the income categories in World Bank data) are derived from cluster analysis on per capita income of countries in 1950.									

of this particular table, states comprising the former Union of Soviet Socialist Republics (USSR) are not included in this analysis for the reason of discontinuous data along the entire study period.

Besides the geographical categorization of the aggregate sample, analyses of long-run growth based on different income groups of these countries is also of sizeable significance. The latter is important for explicit and comprehensive investigations of income convergence within the clusters of rich, middle and poor income countries. To avoid the possibility of '*ex-post sample bias*' in the income convergence analysis (as indicated by Delong (1988)), this classification is required to be based on the initial levels of per capita income, which for this dataset is 1950. In the context of income classification, it is worth mentioning that utilizing the gross national income (GNI) per capita based on the *Atlas method*, the World Bank database categorizes countries into four income groups namely low, lower middle, upper middle and the high income groups. However, there is no information available related to this grouping prior to 1970s either in the World Bank database or in any of the studies pertaining to economic growth and/or income convergence.

Therefore, a cluster analysis is utilized as a method for classifying the sample countries into the aforementioned four income groups on the basis of their initial per capita income levels. This analysis is relatively easy to perform in the presence of a single measureable quantity of objects being characterized, which in this particular case is per capita income in 1950. As far as the choice of income as a reference variable is concerned, Durlauf and Johnson (1995) have emphasized the superiority of an income/output variable against other alternatives for dividing a cross-country data into multiple groups. This is also confirmed by the classifications utilized in their study.

In this study, the *agglomerative form of Hierarchical cluster method* is used in which each object at the beginning is considered as a one-member cluster. Based on an appropriate method of linkage between members of the group, the number of members in a cluster continues to increase in subsequent steps [Bartholomew et al. (2008)]. Because of its feature of generating the clearest picture, the linkage method utilized for clustering is *Ward's method*. This method is specifically designed for metric variables and is based on a measure of sum of squares. Moreover, the distance

between objects is calculated with the most commonly used measure of *Euclidean Distance*, which specifically pertains to the continuous variables [Bartholomew et al. (2008)]. The cluster method was applied using SPSS-18 and according to the results, only 12 countries were in the high income group in 1950 with the real per capita income equal to or higher than \$6770. Moreover, 13, 28 and 84 countries are in the upper middle, lower middle and low income categories respectively.¹¹

Besides the above, discussion on trends of per capita income summarized in Table 2.1 necessitates a prior explanation for each of the focused descriptive statistics. The median is used as a measure of central tendency rather than a usual option of the mean; because exceptionally high per capita GDP for oil rich countries may bias the average value of the sample.¹² The income spread variable, calculated as the ratio between the highest and the lowest per capita GDP of countries, will illustrate an approximate pattern of the income distribution in a region. Finally, the value of average per capita GDP growth rate for the sample period will be utilized to examine an overall economic performance of the regions during an entire time length of 59 years. This average growth rate is based on the region's per capita income calculated by dividing the total GDP of a region with its total population in a year.

A comparison of median income values for the initial and terminal year shows an approximate threefold increase in per capita GDP of the world countries over the period 1950-2008. The world with a total population of 2.5 billion in 1950 had a median real per capita income level of \$1,259 which has risen to \$3,987 in 2008 along with a much higher population of 6.8 billion. The ratio entailing highest per capita GDP to that of the lowest in the sample has also increased from 105 in 1950 to 127 in 2008; indicating larger per capita income differences among the world countries. Separate illustrations for each of the continents revealed that income trends in Latin America & the Caribbean region are similar to that of the world sample. The region has also exhibited an increase in the median per capita along with a higher

¹¹The high income group includes four oil countries namely, Qatar, Kuwait, UAE and the Venezuela, while the other countries of the group are Australia, Canada, Denmark, New Zealand, Switzerland, Sweden, USA and the UK. The upper middle income category encompasses Netherlands, Belgium, Norway, France, Argentina, Uruguay, Finland, Germany, Austria, Trinidad and Tobago, Chile, Italy and the Ireland.

¹² One of the disadvantages of average is its implausibility in the presence of extreme values in a data series.

income differences among countries within the Continent. Likewise, average income growth rates for the world and Latin American samples are 2.2% and 1.8% respectively.

The Asian and the European samples, each, have indicated a six fold increase in their median income. More importantly, smaller values of the ratio between the highest and the lowest income also typify a decrease in income differences for both regions, although the European sample only exhibited a slight reduction. This particular diminution is enormous for the Asian sample which has also shown a higher average income growth of 3.6% compared to 2.8% value for the European sample. However, on account of the earlier industrialization and the consequent sustained period of modern economic growth since 1870, Europe was already one of the highest income regions in the world in 1950, with the median per capita income level of \$3,706 [Crafts and Toniolo (1995)]. In this context, Jones (2002) underscored a favorable natural environment, technological progress, expanded markets and better political structures as plausible causes for Europe's primacy. In contrast to the region of Europe, Asia had managed a median income level of \$960 in the year 1950. Moreover, per capita income differences among the European countries were insignificant compared to the ratio between the highest and lowest per capita GDP for two of the developing regions of the sample, namely Asia and Africa. But, considering the fact that Asian region accounts for 60% of the world population, its highest average per capita growth figure for the period 1950-2008 is momentous [see last column of Table 2.1].

Furthermore, with the highest per capita GDP levels both in 1950 and 2008, the high income countries of Western Offshoots have exemplified a threefold increase in their median income. Maintaining an average income growth rate of 2.1%, the region has shown a constant pattern in their minor income spread. Conversely, the continent of Africa with its lowest per capita GDP levels for the initial and terminal sample periods has also revealed a startling picture regarding the long-run income spread within the Continent. The ratio between the highest and the lowest income has indicated an eight fold increase; though, the value of the region's median per capita income has less than doubled during the entire time span. In comparison to other regions, Africa also has the lowest value for the average per

capita income growth equaling 1.2%. However, it is worth noting that according to Maddison's data, the share of African region in the world's population has increased from 9% in 1950 to that of 15% in 2008 due to its consistently high population growth relative to the other regions.

Regional differences in the per capita income levels may mainly be attributed to the specific historical, geographic or structural factors. Asia and Africa being the lowest in median per capita GDP levels in 1950 initially emerged as the least developing regions; primarily because of the colonial rule in both the continents till or after the middle of 20th century. Negative per capita growth of the Asian region (excluding Japan) over the most part of the period 1820-1950 also explains the probable cause of Asia's low per capita GDP level in 1950 [Maddison (2001)]. Conversely, on account of better economic performance prior to 1950, the median per capita income level for Latin America & the Caribbean region was twice as high as for its two developing counterpart's mentioned above. The former is evident from the highest economic growth figures of the Latin American region relative to all other continents during 1913-1950 [Maddison (1995)]. The sizeable industrialization together with rapid urbanization has accounted for the latter [Bulmer-Thomas (2003)]. Besides, it is worth mentioning, that the majority of Latin American countries were established as independent states almost a century before the independence of the Asian and the African regions [Bulmer-Thomas (2003)].

Opposite to these developing areas, the industrialized regions of Europe, North America and Australia had enjoyed the highest income per person in 1950. Specifically, the median per capita income level in the Western Offshoots was double than that of Europe. This gap between per capita incomes of the two regions may be ascribed to relatively poor economic progress of Europe during the thirty years of wars and economic depression, spanning 1914-1945. Despite the fact that reconstruction in Europe was most rapid in the first five years following WW-II during which GDP for a few western European countries had regained its highest pre-war levels; the overall per capita figure for the region was not recuperated [Crafts and Toniolo (1995); Maddison (1995)].

As far as the per capita income levels of different country groups based on their income classification are concerned, the median per capita GDP level of high income category, \$7959, is approximately double than that of the upper middle group. Similarly, the lower middle group has the median value of \$2189 which is an approximate half of the median per capita GDP of the upper middle income group, \$4253. However, the low income category is lagging behind, with the median per capita income of just \$810. Using a systematic classification based on the cluster analysis, each of the income categories has exhibited lower within group variations in the initial year, 1950. The income spread measured as the ratio between the highest and the lowest per capita GDP levels varied between 2 to 6 and it continued to be minor for the first three income categories even in 2008 as well. Nevertheless, the income spread within the low income group has shown a marked increase across the entire period. The ratio between the highest and the lowest per capita GDP levels in 2008 equals 88 yet, the median income value for the group has only doubled during the period 1950-2008. The median per capita GDP levels has increased by four and five times for the lower middle and the upper middle income groups respectively and it has tripled for the high income group across the whole period.

Referring to the last column of Table 2.1, the average income growth figures for low income and lower middle income groups are the highest, 3.2% and 2.9% respectively. The respective figures for the upper middle and high income countries are 2.6% and 2%. These growth and initial values of per capita income appear to be confirming the convergence implications of NGM. The cluster of poor countries on average has grown faster than that of rich countries. But the difference between growth rates of these groups is minor compared to the gap between initial values of income for the poor and the rich groups. Moreover, the highest variation among incomes of countries in the poorest group is also weakening the likelihood of income convergence among the countries of the world.

The first part of Table 2.1 illustrated the levels of the per capita income for the initial year of analysis which is 1950 while, per capita income figures for 2008 are presented in the second half of the table. The figure for 2008 reflects the continual role of a variety of common, as well as region specific macroeconomic, socioeconomic and political variables. Together all of these have mainly determined

the performance of these economies over the length of 58 years to which the value of 2008 is a manifestation. In this context, the following section will contemplate the long-run economic performance of these regions over the time frame 1950-2008.

2.3.2. Long-run Economic Performance: An Overview

A summary of the historical trends of per capita income and population by illustrating the decade averaged growth rates of these two variables in each of the categorized groups is presented in Table 2.2. In this particular account, because of the availability of aggregate level data for the former USSR states, the category of Europe appears twice with the respective inclusion and exclusion of the USSR states. The question of including these former USSR states in the Asian or in the European continent is critical. In various deliberations, these states are considered as part of the European continent because the official Capital city of former Soviet Union, Moscow, is located in Europe. Alternatively, well-known and commonly utilized databases can also provide a further guideline. Considering them as a separate group, former USSR states are neither part of Asia nor Europe in the IMF database. Conversely, these states are considered with the European region according to the classifications defined by the World Bank, the International Labor Organization (ILO) and the United Nations. Together with keeping in perspective these databases, the geographic categorization in Table 2.2 is also formulated with the primary objective of furnishing the comparative analysis on the per capita income growth of various regions.

Beginning with the decades of 1950s and 1960s, the highest real per capita GDP growth rates were attained by the European Continent because of the Post World War II (WWII) reconstruction in the economy. In the view of some economists, postwar-reconstruction can be considered as a *large positive shock* to Europe's economy [Crafts and Toniolo (1995)]. The Marshall Plan and the Bretton Woods Agreement, particularly, the Bretton Woods era of international monetary system, have also contributed in the expansion [Boltho (1982)]. According to Abramotivz and David (1996), the technological diffusion from the USA was a major determinant of Europe's rapid economic growth particularly that of the Western European countries. The authors further asserted that better macroeconomic

policies focusing on parallel development of social infrastructure have supplemented these technological spillovers. Resultantly, these together had a sizeable positive impact on technological development and economic growth of the region. The additional noticeable features of Europe's per capita income growth were the high levels of human capital, the lowest population growth and the approximately equal growth of the Eastern and the Western regions within the Continent [Maddison (1995)].

Table 2.2. Per Capita Income and Population Growth (%): A Chronicle						
Region/Decade	1950s	1960s	1970s	1980s	1990s	2000s
World	2.7 (1.9)	3.0 (1.9)	2.1 (1.9)	1.4 (1.7)	1.4 (1.5)	2.9 (1.2)
<i>Geographic Classification</i>						
Asia	3.7 (2.1)	3.8 (2.2)	3 (2.1)	3.2 (1.9)	3 (1.5)	5 (1.2)
Africa	1.7 (2.2)	2 (2.5)	1.2 (2.7)	-0.5 (2.9)	0 (2.5)	2.6 (2.3)
Europe	3.9 (0.8)	4.0 (0.8)	2.8 (0.5)	1.8 (0.3)	1.6 (0.2)	2.0 (0.2)
Europe with USSR	3.6 (1.1)	3.7 (1)	2.5 (0.7)	1.6 (0.5)	0.3 (0.2)	2.9 (0)
Latin America & Caribbean	2.1 (2.8)	2.3 (2.8)	3.1 (2.4)	-0.6 (2.1)	1.5 (1.7)	2.1 (1.4)
Western offshoots	1.8 (1.9)	3.3 (1.4)	2.5 (1.1)	2.3 (1)	2 (1.2)	1.2 (1)
<i>Income Classification</i>						
High income	2 (1.5)	3.1 (1.3)	2.4 (1)	2.2 (0.9)	1.9 (1.1)	1.5 (0.9)
Upper middle income	4.5 (0.8)	3.9 (1)	2.7 (0.6)	1.6 (0.3)	1.4 (0.8)	1.3 (0.6)
Lower middle income	4.1 (1.8)	6.1 (1.8)	3.2 (1.9)	1.2 (1.7)	0.7 (1.4)	1.7 (1)
Low income	2.9 (2.1)	2.1 (2.3)	3.1 (2.2)	2.8 (2)	3.3 (1.7)	5.4 (1.4)
Source: <i>Author's calculations based on Maddison's data</i>						
This Table reports the decade average growth rates of real per capita income and population. Values in parenthesis are the average annual population growth rate. For further notes, see Table 2.1.						

Only slightly behind Europe regarding its per capita income growth, the continent of Asia positioned itself as the second highest income growing region during the aforementioned decades. However, in view of the fact that the population growth for the Asia was much higher than that of Europe; the economic growth figure for Asia was also the highest. The independence of nations coupled with the

effective infrastructural development policies and accelerated international trade with the resultant higher levels of domestic investment are considered as some of the constituents of Asian economic growth [Maddison (2001)]. Additionally, economic progress can be well explained by the technological development in the leader country, USA, and the parallel productivity catch-ups by the follower Asian nations. Because of being further from the productivity frontier, the Asian continent has realized highest gains from the technological diffusion in that period [Maddison (2001)].

In contrast, the relatively modest growth of the Latin American countries was attributed to low international trade and the consequent slow technological catch-ups [Bulmer-Thomas (2003)]. Protectionist policies in the region have not only reduced the size of the trade but also resulted in inefficient industrialization and the ensuing low economic growth. The pursuance of the inward oriented development strategy was not historically based in the region, because since independence it was generally reliant on the export-led economic growth until the Great Depression of 1930s [Bulmer-Thomas (2003)]. Because of the worst impact of the latter, the import substitution industrialization (ISI) gradually began shaping the economic policy and continued till its apex during the decade of 1960s [Bulmer-Thomas (2003)].

Owing to the long history of industrialization, trade liberalization, mass production and technological development, income growth figures for the category of Western Offshoots were fairly good and consistent over the entire time-span, particularly for the decade of 1960s [Maddison (1995)]. On the other hand, though positive and modest, the slowest income growth figures for the decades of 1950s and 1960s were demonstrated by the African region. The low level of industrialization, poor infrastructure and political instability were the conceivable basis for the latter [Ndulu et al. (2007)].

The time-span of 1950-73 is termed as the *Golden Age* in the history of economic development because of being characterized with a secular trend in income growth [Maddison (1991)]. Distinctively, this term is used for the European economies though few historians generalized it to typify the economic performance of all the countries during that specific time period. However, the increasing trend in the world income growth was reversed after 1973 mainly because of the breakdown

of the Bretton Woods exchange rate system and the OPEC oil price shocks [Blinder and Rudd (2008)].

This downturn in economic growth was observed to a great extent in Europe, where the two oil price shocks of 1973 and 1979 caused high inflation and the consequent terms-of-trade shock and the balance of payments problems during 1973-83 [Maddison (1991)]. The succeeding macroeconomic policy focus on the control of inflation caused acceleration in the average unemployment rate from 2.4% in the golden age to 6.8% during the period 1984-93 [Maddison (1991)]. Therefore, the per capita income growth fell from 4.1% in 1960s to 1.7% and 1.8% during the decades of 1980s and 1990s respectively. In the western European region, a process of de-industrialization began and during the next two decades the services sector, in place of the manufacturing sector, emerged as a key to economic growth [Crafts and Toniolo (2008)]. On the other hand, the region of Eastern Europe was confronting even worse macroeconomic instability on account of both, the external shocks and the transition to capitalism. In another view, because of the strict product market regulations; lower levels of investment, innovation and the consequent sluggish total factor productivity (TFP) growth contributed towards the overall European economic slowdown [Griffith and Harrison (2004)]. However, rapid globalization and the resultant technological progress along with better institutions and policy reforms are considered as the major sources of Europe's per capita income growth revival in the last fifteen years [Crafts and Toniolo (2008)].¹³

Compared to that of Europe, income growth for the Western Offshoots has not declined a great deal, during the decades of 1970s and 1980s, relative to its value in 1960s. The oil price shocks and the subsequent rising inflation have an impact on the labor productivity growth, unemployment and thus on the economic growth. But due to the flexible product market regulations, this region proceeded well in terms of its per capita income growth [Griffith and Harrison (2004)]. Moreover, resurgence in labor productivity growth during the mid-1990s is mainly considered a source for the persistence of per capita income growth in the recent decade [Maddison (1995)].

¹³ Prior of course to the current economic crisis.

One of the worst performing regions during the sluggish growth period of the world economy was the Latin America & the Caribbean. Initially, for the decade of 1970s, the ISI was considered to be conducive for the income growth which is also evident from per capita income growth figure for the region being higher than the world average. However, owing to the reduced export earnings from the primary and the high cost manufacturing products along with the simultaneous rise in the imports of capital goods; the policy of ISI caused the continual balance of payments deficit and the subsequent rising external debt. The oil price shocks of 1970s with its consequent mount in the petroleum prices have also contributed to the rising external debt of the Latin American countries. The external shocks together with the recession of 1970s resulted in hyperinflation and a debt crisis during 1980s [Pastor (1993)]. During the decades of 1970s and 1980s, values of average inflation rate for Latin American region were 39.4% and 149% respectively [Dietz (1995)]. In the economic history of the region, the decade of 1980s is termed as the *lost decade* due to the worst macroeconomic instability and negative income growth ensuing higher income inequality and poverty [Pastor (1993)]. The extent of poverty is obvious from the fact that, 41% of the households in the region were living below the poverty line in 1990 [Bulmer-Thomas (2003)].

This massive crisis of 1980s was followed by a policy shift via gradual implementation of neoliberal reforms with the initiation of processes of privatization and globalization in the region. Though slow and unstable, income growth was positive during the decade of 1990s while the latest decade has observed further improvements in the region's income growth [Solimano and Soto (2005)]. The resurgence in per capita income growth during the last two decades is accredited to the structural and stabilization reforms resulting in lower inflation rate and higher productivity growth in the region [Loayza et al. (2004)].

One of the illuminating comparisons regarding the study of per capita income growth over the last three decades has been the two completely opposite examples of the Asian and African continents as the best and the worst growing regions respectively. Despite the world economic slowdown in the mid-1970s, Asian region sustained the similar pattern of secular income growth even after the decades of 1950s and 1960s. This is also obvious from Table 2.2 as during the last four decades,

Asia has maintained the highest per capita income growth among different regions of the world. Rapid industrialization and rising manufactured exports sourced from both increasing industrial capability and the low price of labor input mainly explain the Asian income growth [Riedel (1990)]. The former can also be explained by the process of deindustrialization in Western European countries, causing a repositioning of industrial production towards Asia [Crafts and Toniolo (2008)].

Moreover, higher savings, better human capital, good macroeconomic management and technological progress, through the increased international trade and foreign direct investment, are rendered as the key players in the Asian economic growth [Asian Development Bank (1998)]. This virtuous cycle of economic growth was initially confined within the East Asian countries. Subsequently, the Southeast Asian and the South Asian countries have also exemplified better economic performance stimulated by the aforementioned determinants [Asian Development Bank (1998)]. In particular, the East Asian and Southeast Asian economies are also characterized with human resource development, low inflation, and the manageable levels of current account deficit and external debt. Because of their rapid macroeconomic recovery, these countries have sustained long-run economic growth despite the East Asian crisis of 1997 [Jomo (2005)].

Contrary to the remarkable growth performance of Asian countries, the African continent is not only characterized with the lowest per capita growth but the average income growth was negative for the decades of 1980s and 1990s. One of the obvious explanations for the sluggish per capita income growth of African region is the persistently high population growth rate. The average population growth rate was 2.2% for the decade of 1950s, which for the recent decade has increased to 2.3%. Whereas, the average population growth of the Asian region has shown a gradual decline from 2.1% in 1970s to 1.2% in the latest decade of the sample [see Table 2.2]. The delayed and slow demographic transition is considered a probable cause for the high population growth of African region [Ndulu et al. (2007)]. While, the slow economic growth of Africa is derived by both, low levels of factor accumulation and low TFP growth [Bosworth and Collins (2003)]. Lack of good governance, high inflation rates, macroeconomic policy failures, inadequate infrastructure and poor quality of investment climate have resulted in low levels of physical capital

accumulation in these economies whereas, the slow technological progress have also contributed to the sluggish TFP growth [Vishny and Shleifer (1993); Collier and Gunning (1999)].

Besides these macroeconomic and demographic determinants, Africa's economic growth is also constrained by some natural and environmental factors. Firstly, because of being land locked, the geographic isolation in many of the African countries has increased transportation costs of trade [Moss (2007)]. Secondly, characterized by high rates of diseases, the tropic climate of the sub-Saharan African (SSA) region has resulted in lower levels of labor force participation and human resource development [Moss (2007)]. However, for most of the African countries, the income growth figure has illustrated an improvement over the period 1995-2008. Despite a population growth rate of 2.3%, the average per capita growth rate in the recent decade is 2.6%. Trade liberalization and better economic policies have made the largest contributions in the economic recovery and macroeconomic stabilization of the region [Ndulu et al. (2007)].

Up till now, geographic comparisons regarding trends of per capita income growth have focused on the European continent excluding the former USSR states. An interesting comparison for the Continent, at this point, is to analyze the per capita income and population growth rates for Europe inclusive of the USSR region as is given in Table 2.2. During initial decades, 1950s till 1970s, there are only minor differences in the per capita income and population growth figures of these two categories. This implies that during these three decades, the Soviet Union region was parallel to Europe in terms of its economic performance with an average per capita growth rate of about 3% [Ofer (1987)]. The high per capita income growth in the centrally planned economy of Soviet Union can be attributed to rich natural resource endowments, labor growth and to an increase in capital stock [Ofer (1987)]. The large and sustained levels of investment resulted in a diverse industrial base in the Soviet economy. Moreover, growth accounting exercises confirmed that a small proportion of this output growth is contributed by the TFP growth [Easterly and Fischer (1995)].

Unlike the persistent increase in labor and capital stock, TFP growth in the Soviet region began to decrease after 1950s; continued declining and reached an

average level of 0.1% in 1970s [Bleaney (1991)]. This diminution can be explained through the dissuasion of centrally planned economies from the adoption and adaptation of innovations. This has resulted in negative TFP growth in 1980s and has also reduced income growth in the region [Easterly and Fischer (1995)]. The Soviet economic downturn is described as an outcome of the *extensive growth* in which the output growth is mainly driven by growth of factors of production and not the technological development [Ofer (1987)]. Hence, the diminishing returns to each of the inputs cause the decreasing economic growth in the long-run. The burden of rising defense expenditure is considered to be another contributory factor in the declining growth of the Soviet Union [Easterly and Fischer (1995); Ofer (1987)].

Due to the low per capita income growth of Europe along with the poor economic performance of Soviet economy in 1980s, the difference in the growth figures for two European categories in Table 2.2 was minor. The economic stagnation in 1980s, the subsequent breakdown of USSR and the transition of economies in 1990s generated worse output and income growth figures for these States. These economies, of the former Soviet Union, are characterized with *transitional recession*, exemplified by a steep fall in real output following the negative per capita income growth, high income inequality and poverty [World Bank (2002)]. Hence, during the transition period of 1990s, the income growth for the category of Europe inclusive of former USSR is much less than when the latter is excluded.

Nevertheless, the economic recovery in the former Soviet region has started mainly at the end of 1990s, and has caused an overall strong per capita income growth in the latest decade. Resultantly, the category of Europe inclusive of former USSR has a higher average income growth relative to that of Europe only. The rising manufacturing production and exports to industrial countries, higher foreign direct investment because of privatization, tax reforms and financial deepening are the key constituents of this economic expansion [World Bank (2002)].

The last part of Table 2.2 presents the decade averaged per capita and population growth rates for different income groups of world countries. Throughout the first three decades, the highest per capita income growth rate was attained by either the upper middle or the lower middle income groups. Nonetheless, for the next

three decades, the income growth rates have reduced for both of these categories specifically, the decrease is larger for the lower middle income group during the decades of 1980s and 1990s. As far as the population growth is concerned, the upper middle income group has a lower population growth rate compared to that of the lower middle income category. The former cluster for the most part comprises western European countries while the lower middle income category contains more countries from the Latin American continent, along with few from the European, East and West Asian and African regions. The low income category, a combination of majority of Asian and African countries, has an average growth rate of around 2.8% for the first five decades together with the highest population growth figures across the entire time period. This cluster has managed an average per capita income growth of 5.4% in the recent decade because of the higher growth rates for both Asian and African regions during this period. Furthermore with the declining population growth rates, the high income countries on average have performed slightly better in the first half compared to the later part of the study period. These illustrations are similar to the growth performance of western offshoots which is entirely included in this cluster along with four countries each from OPEC group and Western Europe.

Finally, after this brief discussion on the world economic performance during the period 1950-2008, the income growth of various regions for the year 2009 is described in Figure 2.1. One should not read too much into one year's figures, but this income growth is indicative of the fact that all the presently high growing economies belong to the cohort of the developing region while, the respective growth rates for developed countries are modest or low. Therefore, this, apparently, is endorsing the convergence postulation entailing higher growth for the low income regions and vice versa. However, SSA is an exception in this context with its low income growth of less than 1% despite being one of the poorest regions in the world.

2.4. HISTORICAL PERSPECTIVE ON INCOME CLASSIFICATION

The income categorization discussed so far was based on the real GDP per capita of sample countries in the year 1950. However, the recent income categorization by the

World Bank for the year 2008 may furnish an interesting comparison with that of 1950. Consequently, this temporal comparison of income classifications can contribute useful information regarding the subject matter of convergence. In this context more emphasis is given to the previous lower middle and low income countries because of both (i) their poor conditions in 1950 and (ii) the inclusion of a larger number of countries in each category.

Figure 2.1. GDP Per Capita Growth (annual %): 2009

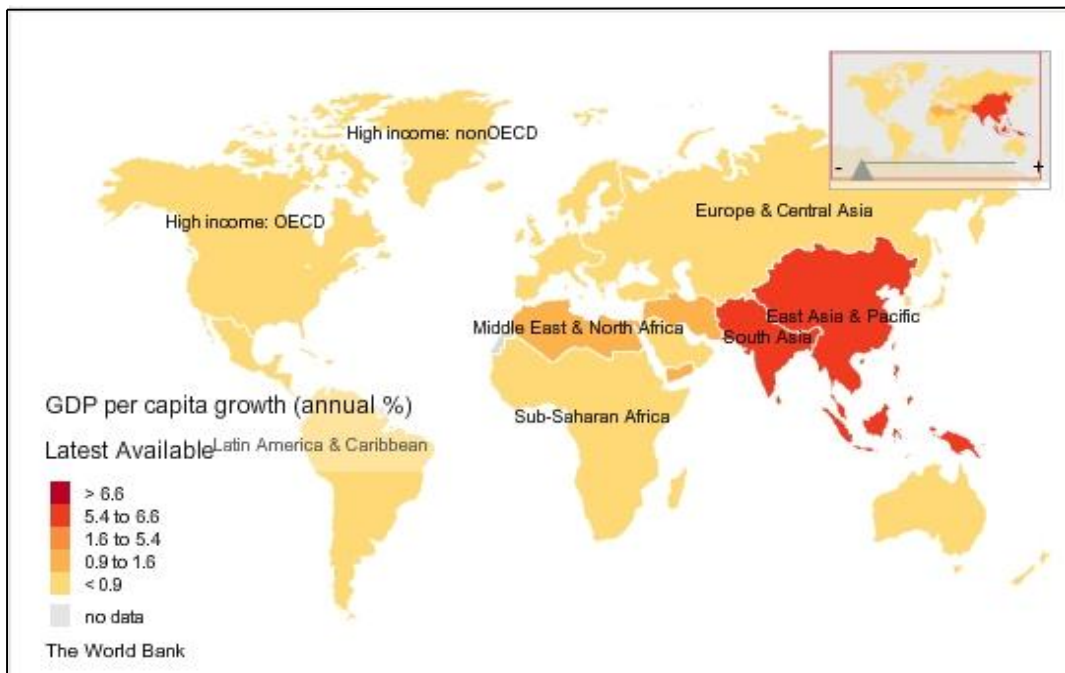
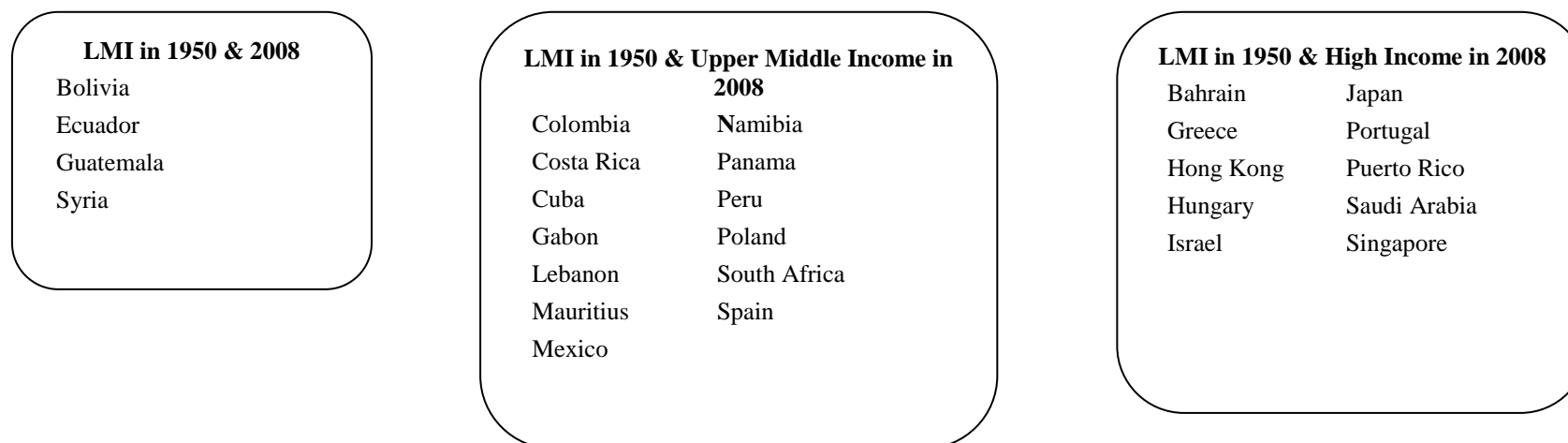


Figure 2.2 illustrates the lower middle income countries of 1950 and their subsequent category in 2008. The majority of the countries have stepped forward towards the upper middle income group in 2008. A number of these have also managed to join the club of high income countries comprising three East Asian, three European, one West Asian and a few oil-rich countries. However, three Latin American countries together with Syria, represented by the box on the upper left corner, have retained the original income category till 2008.

The current income categorization for the low income countries of 1950 is depicted in Figure 2.3. The majority of countries in this category have not progressed towards the higher income levels during the sample period, 1950-2008 as is evident from the number of countries in the lower box. These are predominantly the SSA

Figure 2.2: Income Classification of Lower Middle Income (LMI) Countries in 1950 and 2008



Sources: Author's Calculation for the classification in 1950 based on Maddison's data and the World Bank (2009) for the categorization in 2008.

Figure 2.3: Income Classification for Low Income Countries in 1950 and 2008

Low income in 1950 & Lower Middle Income in 2008			
Albania	Egypt	Lesotho	São Tomé
Angola	El Salvador	Mongolia	Sri Lanka
Cameroon	Honduras	Morocco	Sudan
Cape Verde	India	Nicaragua	Swaziland
China	Indonesia	Nigeria	Thailand
Congo			Tunisia
'Brazzaville'	Iran	Pakistan	
Côte d'Ivoire	Iraq	Paraguay	West Bank
Djibouti	Jordan	Philippines	~

Low income in 1950 & Upper Middle Income in 2008	
Algeria	Jamaica
Botswana	Libya
Brazil	Malaysia
Bulgaria	Romania
Dominican Republic	Turkey

Low income in 1950 & High Income in 2008	
Equatorial G.	
Oman	
South Korea	
Taiwan	

Low income in 1950 and 2008				
Afghanistan	Chad	Kenya	Nepal	Togo
	Comoro			
Bangladesh	Islands	Laos	Niger	Uganda
	Eritrea and			
Benin	Ethiopia	Liberia	North Korea	Vietnam
Burkina Faso	Gambia	Madagascar	Rwanda	Yemen
Burma	Ghana	Malawi	Senegal	Congo, R.
Burundi	Guinea	Mali	Sierra Leone	Zambia
Cambodia	Guinea Bissau	Mauritania	Somalia	Zimbabwe
	Haiti			
Central Afr. R.		Mozambiq.	Tanzania	

Sources: Author's Calculation for the classification in 1950 based on Maddison's data and the World Bank (2009) for the categorization in 2008.

nations alongside a few Asian countries and a Latin American nation, Haiti. On the other hand, some of low income countries have managed to move towards the immediate next category portrayed by the box in the upper left corner in the figure. However, only 10 of the low income countries have moved towards the upper middle income category which includes a mix from Asian, African and Latin American & Caribbean regions. Moreover, with an average income growth value of above 4% each, four of the low income countries have joined the high income club by 2008. Two of these, Equatorial Guinea and Oman, are the oil-rich countries and the remaining two, South Korea and Taiwan, are among the East Asian Tigers.

These two figures are indicative of the fact that the actual convergence phrase of *poor becoming the rich* is in evidence for those current high income countries which had been part of the lower middle and the low income groups in 1950. But an important implication of the aforementioned analysis is that the economic progress of these countries is neither region specific nor it is contained within a specific income category. Likewise, not all the natural resource rich countries are part of a specific income group in 2008. There are variations across different countries in the form of their endowments, structural characteristics and macroeconomic and social policies. Consequently, their economic and social indicators are the outcome of an interplay of all these features.

2.5. CONCLUSIONS

This chapter discussed key theories and historical trends pertaining to the long-run growth and income convergence. The convergence hypothesis introduced by the NGM received a conflicting response from the endogenous growth theories. The earlier theories completely rejected the possibility, but later theorists were in favor of some income convergence across the countries. The second part of the chapter illustrated an up-to-date descriptive analysis on income growth and absolute convergence.

A retrospect on the per capita income levels and long run growth of various categories has illustrated considerable economic expansion for the Asian region compared to that of African and Latin American & Caribbean continents.

Specifically, the African region is the worst performer because of the numerous exogenous and endogenous factors. Likewise, the income spread measure for the initial and terminal years has also indicated the highest increase for Africa. Conversely, the relatively developed regions of the Western offshoots and Europe have shown further progress along with a minimal income spread. However together with the region specific variables, growth figures of all these years have also shared some common recessions which was not always evident in the specific decade averages for the clusters.

Among different income groups, the hierarchy of their average income growth figures is completely opposite to their respective categorization. The low income countries have attained the highest growth and vice versa. Nonetheless, the latter also has the largest value of income spread in 2008. Keeping in perspective the basic idea of *catching up* among countries, it is evident that some of the low income and the lower middle income countries of 1950 have progressed towards higher income categories by 2008. An analysis of the current income classification of previously lower middle and low income countries of the world has illustrated the importance of country specific parameters for the sustainable economic performance of economies.

The evidence for cross-country income convergence on the basis of the existing information is quite vague. Therefore, the question of income convergence necessitates a direct consideration utilizing the actual world data. The major research questions of the thesis are:

- How the convergence literature has evolved over time regarding both the theory and its empirics?
- Is there any evidence of absolute β -convergence among world countries and within its geographic categories, namely, Africa, Asia, Europe and Latin America & Caribbean for the period 1950-2008?
- Following the convergence postulation of the '*poor becoming the rich*', is there any significant evidence for poor countries (low income countries) catching up to the rich (high income countries) over the last half century? Is there any evidence of β -convergence within each cluster?

- Has cross-sectional dispersion among world countries reduced and what's its trend for various geographic and income categories?
- Which geographic region has shown the highest evidence of conditional β -convergence?
- Is there any difference between the estimated β -convergence rate of GDP per worker and GDP per capita and if so how can that difference be explained?
- How two different growth frameworks, namely, the augmented Solow model and Barro's income growth regressions explain the concept of conditional β -convergence?
- Which growth model, the neoclassical growth model or endogenous growth theory, better explains sources of conditional β -convergence?
- Whether institutional quality and/or initial human capital is most important for the income convergence of poor countries?
- Are there any convergence clubs among world countries?
- Is there any single best notion of income convergence? How can results from various approaches of income convergence be compared and synthesized?

Chapter 3.

INCOME CONVERGENCE: EVIDENCE FROM LITERATURE

3.1. INTRODUCTION

A comprehensive analysis of per capita income levels and growth rates across different regions of the world has indicated considerable improvements in the income levels of all countries. Along with the obvious contributions of domestic macroeconomic and policy variables; the role of global/external, natural and environmental factors has been evenly important in determining the economic/income growth of these regions. However, cross-country income spread varies among different groups both for the initial and the terminal years. The accumulated economic performance throughout the entire time span, 1950-2008, has a significant impact on the per capita income levels and its spread in 2008. Despite the information on trends of income and its growth, the question of whether there is cross-country income convergence is still unanswered.

The interrelated subjects of long run economic/income growth and income convergence have always been successful in fascinating the researchers of both theoretical and empirical orientations. The empirical investigations on the convergence hypothesis span over half a century now. These have been augmented by diverse econometric methodologies employed for empirical analyses, based on all kinds of data sets including cross-sectional, time-series and panel data ones. This chapter presents a review of empirical work carried out on the convergence hypothesis in all of its aspects. Part 3.2 presents a review of the empirical literature from around the world on β -convergence. Contrasting notions on the existence of convergence in the neoclassical growth model (NGM) will be described in the third part together with the resultant analysis considering the multiple steady states and club convergence as implied by some endogenous growth models. Applications of

time-series methodology and the notion of stochastic convergence will be illustrated in Part 3.4. The empirical literature on σ convergence is discussed in Part 3.5. Finally, Part 3.6 concludes with deliberations for further empirical analysis. Each of these parts comprises different notions of convergence and their better understanding requires a prior explanation for each, which is given in Table 3.1.

Table 3.1. Definitions of Different Notions of Convergence	
Concept	Definition
β -convergence	Negative relationship between the growth rate of GDP per capita/worker and its initial value in a regression framework
Absolute convergence/Unconditional Convergence	Negative relationship between the growth rate of GDP per capita and its initial value in a simple regression framework involving only two variables
Conditional β -convergence	Negative relationship between the growth rate of GDP per capita and its initial value after controlling for macroeconomic variables determining the steady state of cross-sectional units
Conditional convergence-II	Alternative term for the intra-country absolute convergence
Local convergence	Convergence among a specific group of countries
Global convergence	Convergence across all the countries in the world
σ convergence	Over time reduction in income dispersion among cross-sectional units
Stochastic convergence/ Catching-up tendency	Trend stationarity of per capita income of a region relative to that of an entire group
Deterministic convergence/ Long-run convergence	Mean stationarity of relative per capita income of a region
Time series β -convergence	Statistically significant and opposite signs for point estimates of the intercept and the trend coefficients in a deterministic trend function based on the relative income (RI), i.e. $RI_t = \mu + \beta t + v_t$
Absolute stochastic convergence	No individual fixed effects in panel unit-root/stationarity test
	All the paired income deviations are level stationary
Conditional stochastic convergence	Presence of country specific fixed effects in panel unit-root/stationarity test
	Some but not all of the income deviations are level stationary
Club convergence	Conditional convergence among the countries with similar initial conditions

3.2. β -CONVERGENCE

Indebted to the Solow model for its theoretical naissance, the debate on the concept of convergence continues to derive inspirational motivation from variously diverse

empirical findings which are based on a wide range of econometric methodologies. Indeed, the relevant literature provides a conveniently consistent framework to help organize the review of empirical studies on the subject into distinct sections. Section 3.2.1 takes into account the earlier work on the topic followed by the second and third sections with their respective deliberations on the across and the within country evidence using both the cross-sectional and the panel data.

3.2.1. Earlier Debate and Concept of Conditional Convergence

The availability of relevant and reliable statistical data is the most critical prerequisite for a meaningful empirical exercise. Study of the *Solovian* concept of convergence was conditional on the availability of statistics, at least for a few countries, furnishing size of output per worker over a long period of time. Maddison (1982) made the most significant pioneering contribution by constructing a macroeconomic dataset for 16 industrialized countries covering 9 key periods over the time-period 1870-1979.¹⁴ A comprehensive follow up attempt was made by Summers and Heston (1984) who compiled per capita GDP data for a much larger and heterogeneous sample of 72 countries over the period 1950-80.

Utilizing Maddison's (1982) dataset, preliminary empirical findings on the catching up hypothesis were contributed by Abramovitz (1986) and Baumol (1986) using the variable of average labor productivity. Abramovitz (1986) has validated the convergence hypothesis based on the estimates of relative variance and rank correlation coefficient. Analogous conclusions of convergence by Baumol (1986) were derived primarily from the estimation of a simple regression equation depicting a strong, negative and significant relationship between the growth rate of GDP per work hour and its initial value. Furthermore, Baumol (1986) has also investigated the convergence hypothesis for (i) poor, (ii) middle income and (iii) centrally planned economies. Results demonstrated *divergence* for poor economies and varied but less

¹⁴ A parallel but relatively limited data set was formulated by Matthews et al. (1982) for 7 industrialized countries from 1870-1973 but higher spatial and temporal coverage of Maddison's data enhanced its efficacy.

intensity of convergence within other groups relative to that of industrialized countries.¹⁵

Baumol's analysis was followed by the contribution of Delong (1988), who criticized Baumol's regression analysis and its validation of strong convergence among 16 developed countries. The criticism was based on the sample selection and on an inappropriate estimation technique. Hence, for the same regression, once the biases are adjusted with the formulation of both an ex-ante sample of *once rich* 22 countries and a modified methodology adjusting the measurement error; the resultant conclusion supported either no convergence or divergence instead of otherwise. In their rejoinder, Baumol and Wolff (1988) reaffirmed convergence among developed countries through the application of piecewise linear and quadratic regressions. Results have revealed the convergence and weak divergence among the high and low income countries respectively and the slowdown of income convergence among industrialized countries after 1973. Conversely, on the basis of a parameter stability test, Dowrick and Nguyen (1989) have confirmed a consistent and stable trend of income convergence for the industrialized countries. Their study also intended to investigate the sources of convergence for 32 OECD countries. Results have confirmed that the income convergence in the sample countries is sourced from the TFP catch up rather than that of factor intensity.

The initial empirics on convergence theory were followed by a comprehensive analysis of the topic by Barro and Sala-i-Martin in their several researches of varying breadth and depth. By taking a sample of 48 states of the USA, Barro and Sala-i-Martin (1990) have examined the absolute convergence in an open economy framework of the NGM.¹⁶ Contrary to the OLS estimation of the simple regression of income growth on its initial value, the specific functional form of the absolute β -convergence regression equation derived from NGM is:

¹⁵ Baumol (1986) described the strong income convergence among the group of rich countries as an indication for the formation of a convergence club.

¹⁶ Keeping in perspective the impracticality of closed economy NGM for these sample states, it was modified for an open economy framework. Interestingly, the open economy formulation of the model by incorporating higher factor mobility and technological diffusion further reinforced the implications for convergence. However, Barro et al. (1995) asserted that the quantitative impact of capital mobility on convergence is generally small.

$$\left(\frac{1}{T}\right)\ln\left(\frac{\hat{y}_{iT}}{\hat{y}_{i0}}\right) = a - \left[\frac{(1 - e^{-\beta T})}{T}\right]\ln(\hat{y}_{i0}) + u_{i0,T} \quad (3.1)$$

‘ T ’ is the total time period. In this equation, the convergence coefficient on initial income, β , is in non-linear form; therefore, it is estimated utilizing the non-linear least squares technique. The obtained results confirmed significant convergence at a rate of 2% per annum. The study also endorsed convergence between the original OECD member countries at an annual rate of 1%. Utilizing the data on per capita GDP, analogous results of 2% rate of convergence were also reported for 73 Western European regions belonging to 7 countries [Barro et al. (1991)].¹⁷

However, Barro (1991) contradicted these earlier findings with proof of no convergence for a broad and heterogeneous sample of 98 countries; hence validating the divergence proposition of early endogenous growth theory.¹⁸ While inferring from this theory, Barro (1991) assigned the underlying cause of observed divergence to the differences in the initial level of human capital stocks between countries. The study therefore concluded strong convergence in the identical sample but with the modified model which incorporates the initial level of human capital stock of countries in the regression equation.¹⁹ The succeeding literature largely favored the argument of absolute divergence among countries, as suggested by several studies including that of Barro (1991).²⁰ Nevertheless, Barro (1991) underscored the existence of convergence towards the separate levels of steady states of individual countries.

¹⁷ These findings were not supported by Paci (1997) whose analysis suggested no convergence in per capita income between 109 territorial units of 12 European countries for the decade of 1980s. However, another parallel finding of his study is 1.2% rate of convergence in labor productivity among the sample countries which, when extended to sector wide analysis, shows highest rate of convergence in industrial sector, followed by services, and no convergence in the agricultural sector. In contrast, Wolf (1994) has corroborated strong labor productivity convergence in primary and tertiary sectors of the world while the opposite is confirmed for the manufacturing sector of the economies.

¹⁸ Quite opposite to these findings, the study by Cole and Neumayer (2003) concluded absolute convergence in a broad sample of 110 countries for the period, 1960-96. This single evidence of absolute convergence is based on population weighted per capita GDP.

¹⁹ Existence of significant convergence in the samples of Barro (1991) and in 22 *once rich* countries of Delong (1988) was subsequently endorsed by Knack (1996), after independently controlling for human capital and institutions in a cross-sectional regression. Author postulated, and later substantiated as well, that the quality of institutions is the key determinant of catching up potential of a country.

²⁰ Another endorsement for the existence and strong persistence of absolute divergence among developed and developing countries is the study by Pritchett (1997), who showed the evidence for poor countries through backward simulation of per capita GDP till 1870.

The literature cited above and summarized in Table 3.2 introduced a new phenomenon, later termed as *conditional convergence*. Diverse parameters of economies generate different levels of the steady state, and estimation of convergence necessitates controlling for such factors in regression, therefore termed as conditional convergence.²¹ Alternatively, analysis of absolute convergence in an apparently similar group of countries, or of regions within a country, is parallel to controlling for differences in the steady state. Therefore, this was also termed as conditional convergence or *Conditional Convergence (II)* [Sala-i-Martin (1996a)]. Subsequently, the concept of β -convergence also encompasses conditional convergence of either type, which will be discussed in the following sections.

3.2.2. Cross Country Conditional β -Convergence

This section reviews a cluster of studies analyzing cross-country conditional convergence. The majority of the researches are based on the estimations of the basic and augmented Solow models using either the cross-sectional or the panel data or both. Analyses in these studies are sourced from a range of estimation techniques including the OLS, the instrumental variable (IV) and the Generalized Methods of Moments (GMM). Furthermore, some of these studies have also incorporated a variety of additional macroeconomic variables in the income growth regressions.

Comprehensive pioneering work on the conditional convergence through cross-sectional data was contributed by Mankiw et al. (1992), in their study on both the original and augmented forms of the Solow model.²² The first phase of the authors' analysis confirmed absolute divergence within the sample of countries. However, the subsequent estimation of convergence was undertaken using a multiple regression model derived from the NGM by controlling for differences in population growth rate and saving rate, in the following form:

²¹ The researchers also argued that NGM was misinterpreted in its implication for convergence as the model entailed conditional rather than absolute convergence with the view that each country should catch up to the *respective* steady states instead of a common one [see, Barro and Sala-i-Martin (1992); Mankiw et al. (1992)].

²² Earlier, a study on the determinants of economic growth by Kormendi and Meguire (1985) using the post-war data of 47 countries has verified conditional convergence. However, a follow-up study by Grier and Tullock (1989) while utilizing a larger dataset has confirmed mixed results regarding conditional convergence of the full sample and its various sub-groupings [For further details, see, Islam (2003a)].

Table 3.2. Earlier Evidence on Convergence Hypothesis Based on Cross-Sectional Methodology

Author/Year	Nature & Number of Cross Sectional Units	Data Period	Methodology	Key Conclusions
Abramovitz (1986)	16 industrialized countries	1870-1979	Relative variance	Convergence
Baumol (1986)	16 industrialized countries	1870-1979	OLS estimation of simple regression of income growth on initial income	Convergence
	72 countries	1950-80		Strong convergence for the rich income countries, less convergence for the middle income and divergence for the poor group
Delong (1988)	Once rich 22 countries	1870-1979		No convergence
Baumol and Wolf (1988)	72 countries	1950-80	Piecewise linear and quadratic regressions of growth on basic income	Convergence among high income and weak divergence in low income countries
Dowrick and Nguyen (1989)	32 countries of the OECD	1950-85	Regression of output on initial income, labor and capital stock	Income convergence sourced majorly from TFP catch-up
Barro and Sala-i-Martin (1990)	48 States of the USA	1840-1988	Non-linear least squares estimation of unconditional convergence regression	Convergence at the rate of 2% per annum
	20 original member countries of OECD	1950-85		Convergence at the rate of 1% per annum
Barro and Sala-i-Martin (1991)	73 Western European regions of 7 countries	1950-85		Convergence at the rate of 2% per annum
Paci (1997)	109 territorial units of 12 European countries	1981-90	OLS estimation of simple regressions for per capita income and the labor productivity	No converge in per capita income and convergence in labor productivity at the rate of 1.2%
Barro (1991)	98 countries	1960-85	Non-linear least squares estimation of unconditional convergence regression involving per capita GDP	Absolute divergence
Cole and Neumayer (2003)	110 countries	1960-96	Non-linear least squares estimation of unconditional convergence regression involving population weighted per capita GDP	Absolute convergence

$$\ln \left[\frac{\hat{y}(t)}{\hat{y}(0)} \right] = gt + (1 - e^{-\beta t}) \ln A(0) + (1 - e^{-\beta t}) \left(\frac{\alpha}{1 - \alpha} \right) \ln(s) - (1 - e^{-\beta t}) \left(\frac{\alpha}{1 - \alpha} \right) \ln(n + g + \delta) - (1 - e^{-\beta t}) \ln(\hat{y}(0)) \quad (3.2)$$

In this equation, \hat{y} is the output per worker and $A(0)$ is the initial level of technology. The convergence coefficient is denoted by β . The estimation of equation (3.2) significantly reversed the former evidence in favor of convergence. Moreover, the incorporation of human capital as an explanatory variable in the Solow model further enhanced the size of the convergence coefficient. The authors have also analyzed the convergence for two subsamples of 75 intermediate and 22 OECD countries and their results completely conformed to previous evidence.²³

A very significant contribution of Mankiw et al. (1992) ought to be recognized as the reinstatement of NGM and its empirical validation, specifically against the backdrop of the earlier recognition of endogenous growth theory. However, the value of R^2 was low for the OECD sample compared to the value of R^2 of 0.78 for the sample of 98 countries. This issue was later addressed by Nonneman and Vanhoudt (1996) who have further augmented the NGM by incorporating technological know-how as another form of capital. Nonneman and Vanhoudt reported an even higher explanatory power of their model along with the conclusion of a higher rate of convergence for the similar OECD sample. Murthy and Chien (1997), further followed up the analysis of OECD growth with the introduction of a new denomination of human capital stock, measured as weighted average of enrollment at primary, secondary and tertiary levels of education. Maintaining the similar functional form of regression as Mankiw et al. (1992), the estimation with the least absolute error (LAE) technique generated a higher than typical, 4% rate of convergence for the sample.

Despite many auxiliary augmentations, the methodological formulations of Mankiw et al. (1992) remained widely popular in later empirical studies on conditional convergence with both cross-sectional and panel data. Two examples

²³ One very unusual implication regarding the evidence of conditional convergence in Mankiw et al. (1992) was contemplated by Cho and Graham (1996) who illustrated that relatively poor (rich) countries catch-up to their steady state from above (below) and thus poor countries are above their steady state levels.

with cross-sectional data are the studies by Murthy and Ukpolo (1999) and Dobson and Ramlogan (2002) for the African and Latin American samples respectively. The former estimated a 1.7% rate of conditional convergence for Africa while, the latter concluded little evidence of conditional convergence for the whole study period.²⁴ A more recent cross-sectional data based conditional convergence study is furnished by Karras (2010) focusing on various geographic regions. Finally, in the sensitivity analysis of cross country growth regressions using extreme-bounds analysis (EBA), Levine and Renelt (1992) have affirmed the significance and robustness of the coefficient on conditional convergence for the period 1960-89. This was conditional on the inclusion of initial level of investment in human capital in the growth regressions and was not confirmed for the sub-period 1974-89.

Regardless of their enormous contribution to the literature on the convergence hypothesis, the critical aspect of empirical studies reviewed above is the assumptions on the nature of initial technical efficiency, $A(0)$, in equation (3.2), and its relation with the explanatory variables of the model. This term plausibly incorporates a country's level of technology, resource endowments and/or institutional setup etc. However, cross-sectional estimations of growth regressions cannot incorporate the individual country effects for $A(0)$ and it is assumed constant. This may cause estimation problems on the basis of omitted variable bias and consequently may reduce the reliability of results. Similar notions were also maintained by Goddard and Wilson (2001) in their evaluation of cross-sectional, pool and panel data methodologies for convergence. Problems pertaining to parameter heterogeneity in these regressions are examined using Monte Carlo simulations and in the presence of heterogeneous individual effects, panel estimation appears the most plausible option of all.

This problem was addressed in the succeeding growth and convergence empirics as well. Knight et al. (1993) have applied panel data techniques on the model formulated by Mankiw et al. (1992) hence, fundamentally controlling for cross country differences in aggregate production functions. The model was further

²⁴ Murthy and Ukpolo (1999) estimated the conditional convergence with augmented form of Solow model and human capital accumulation is measured as weighted average of enrollment rates at all three levels. The authors attributed this smaller than usual size of convergence coefficients to the structural problems in the African Continent.

extended by incorporating trade openness and public infrastructure as two probable determinants of technical change. Given the results, the authors reported a threefold increase in the earlier value of the speed of convergence. Subsequently, utilizing the panel data framework, Loayza (1994) and Islam (1995) illustrated a dual increase in the usual 2% size of the convergence coefficient. A follow up study by Sala-i-Martin (1996a) has registered a 2% rate of conditional convergence after additionally controlling for some political variables in the growth model.

An important modification in the estimation technique was introduced by Temple (1998) who has used the Reweighted Least squares regression (RWLS) to deal with the particular problems of fixed effects panel data estimation. The obtained results endorsed the earlier findings of Mankiw et al. (1992) for the broader sample; but, for the OECD sample the new technique exhibited noticeable improvement regarding R^2 and estimated convergence rate.²⁵ Finally, the study reported the highest rate of convergence in the lowest quartile which represented the poor country strata of the broader sample. Subsequently, Miller and Upadhyay (2002) have augmented the analysis by including the TFP, in addition to the real GDP per worker. Their findings suggested absolute TFP convergence, while conditional convergence was observed for both GDP and TFP at the rates of 4% and 6% respectively. However, the TFP convergence of high income countries fell short of the corresponding figure reported for the low and middle income country groups.²⁶

During the first decade of empirical investigations for the convergence hypothesis, worldwide numerous studies, including those already reviewed, mainly focused on the estimates of the *rate of convergence* from the cross-sectional and panel datasets. Later researches, however, have contemplated various methodological dimensions resulting in further augmentation of the cross-country growth framework including plausible determinants of long run income growth. The study of Andres et al. (1996) is a case in point that has incorporated some important macroeconomic variables in their model including the inflation rate, exports growth and public sector

²⁵More importantly, the author illustrated the sensitivity of previous conditional convergence estimates towards measurement error of initial income and has used methods of moment's correction as well.

²⁶ Perhaps, at this point it is worth mentioning that for the estimation of conditional convergence, the authors preferred fixed effects methodology of simple regression over the estimation of a multiple regression model with panel data.

expenditure. However, these findings do not appear to suggest any noteworthy revision to the prior evidence on OECD convergence.²⁷

In contrast, Barro (1998 and 2003) have utilized first difference and IV methods of estimation to study world income convergence.²⁸ The explanatory variables of the model were also further extended; beyond the inflation rate and public sector expenditure to include life expectancy, fertility rate, terms of trade and a rule of law index.²⁹ Due to an increasing number of plausible regressors for income growth regressions, there was a need for the robustness analysis of these growth regressors. As already mentioned, the first sensitivity analysis of growth regressions was conducted by Levine and Renelt (1992). Further notable contributions were made by Sala-i-Martin (1997), Temple (2000), Fernandez et al. (2001), Sala-i-Martin et al. (2004) and Hendry and Krolzig (2004). Hendry and Krolzig (2004) have favored the '*general to specific approach*' for the selection of growth regressors; while, Temple (2000) has proposed the EBA method of Levine and Renelt (1992) to solve the problem of '*model uncertainty*'. In contrast, Fernandez et al. (2001) and Sala-i-Martin et al. (2004) have respectively utilized the Bayesian model averaging (BMA) and Bayesian Averaging of Classical Estimates (BACE) approaches for model selection.³⁰

Although panel data inference has helped resolve the problem of correlated country specific effects, the existence of endogenous explanatory variables and/or lagged dependent variable could still cause the inconsistent and biased estimates. Caselli et al. (1996) have tackled this critical concern by estimating the basic and augmented Solow models utilizing the first-differenced GMM technique which resulted in marked variation in regression output for the same dataset. More

²⁷Earlier studies on OECD convergence warranted a methodological augmentation of the growth framework ensuring parameter stability of regression coefficients across sub-periods and subsamples of countries; an objective that remained unfulfilled even in Andres et al. (1996).

²⁸ Application of the instrumental variable technique by Barro (1998) generated only a 2% rate of convergence which, because of estimation bias in the previously reported 4% rate, is favoured by the author as a more reliable result.

²⁹ Adhering to panel data methodology each with fixed effects and instrumental variable technique, Milanovic (2003) has illustrated interesting findings regarding conditional convergence evidence for 17 rich countries. According to the results, countries did not catch-up towards each other during the per-war era of 1870-1913 while, depicting strong convergence in the inter-war period ranging from 1918-38. The latter period is also characterized with disintegration of the world economy.

³⁰ In a recent study, Feldkircher and Zeugner (2012) have confirmed that robustness results of Bayesian model averaging of Sala-i-Martin et al. (2004) are quite stable for various data revisions.

specifically, a threefold increase in the estimated speed of convergence was observed compared to the size of the corresponding coefficient in the original estimates. Another application of various forms of GMM and instrumental variable methodologies was contributed by Lee et al. (1998). Contrary to the earlier results of a threefold increase in the convergence coefficient, the study has corroborated a 2-4% rate of convergence for the sample. Finally, criticizing the first-differenced GMM estimation technique on the basis of finite sample bias related to weak instrumental variables, Bond et al. (2001) have alternatively suggested and utilized a system GMM estimator for the cross-country growth regressions. Instead of the very high estimates for the convergence coefficient as Caselli et al. (1996), the authors have reported 2-4% convergence rate for the identical sample.

Other variants of estimation techniques utilized in panel data estimations of basic conditional convergence equation are based on heterogeneous panel data. One of these is the study by Evans and Kim (2005), who have utilized a dynamic random variable model and have concluded there is conventional 2% rate of conditional β -convergence for Asian countries. Another related study by Ismail (2008) has examined the unconditional and conditional β -convergence among ASEAN-5 countries using the pooled mean group estimator (PMGE) and have confirmed both absolute and conditional convergence among these countries. However, according to Masron and Yusop (2008), not only the convergence among ASEAN-5 countries is conditional on trade openness, but external shocks cause income divergence among these countries.

These aforementioned numerous studies pertaining to the analysis of cross-country conditional convergence are summarized in Table 3.3. Almost all of the stated results have endorsed the prevalence of conditional convergence at different rates among a variety of samples. In spite of the most frequent value of around 2% for the coefficient on conditional convergence, the rate also ranges between 4-10% for some other samples. This stands in complete contrast with the weak evidence of absolute convergence among the broad sample of countries as reported in Table 3.2. The use of panel data methodology has increased the size of convergence coefficients compared to their respective values with the cross-sectional data. Likewise, for some

Table 3.3. Cross Country Conditional Convergence				
Author/Year	Number & Nature of Countries	Data Period	Methodology	Key Conclusions on the Rate of Conditional Convergence
<i>Analysis Based on Original/Augmented Solow Model Formulated by Mankiw et al. (1992)</i>				
Mankiw et al. (1992)	98	1960-85	OLS estimation with cross-sectional data	1.4%
	75 intermediate			1.8%
	22 OECD			2%
Nonneman and Vanhoudt (1996)	22 OECD	1960-85	OLS estimation with cross-sectional data	2.9%
Murthy and Chien (1997)			Least absolute error (LAE) technique with cross sectional data	4%
Murthy and Ukpolo (1999)	37 African	1960-85	OLS estimation of cross-sectional data	1.7%
Dobson and Ramlogan (2002)	19 Latin American	1970-98		Weak and insignificant
Karras (2010)	62	1950-2007		0.5% to 2%
Knight et al. (1993)	98	1960-85	Minimum distance method of Chamberlin using panel data	6%
Loayza (1994)			Minimum distance method of Chamberlin using panel data Least Squares Dummy Variables method	5%
Islam (1995)				4% with each method of estimation
Temple (1998)	98	1960-85	Reweighted Least Squares regression with panel data	1% for aggregate sample and 9% in poorest group, no in two middle quartiles and 1.8% in richest group
	22 OECD			3.6%
Caselli et al. (1996)	97	1960-90	First differenced GMM with panel data	6%
Lee et al. (1998)	22 OECD	1950-90	IV and first differenced GMM techniques with panel data	2-4%
Bond et al. (2001)	97	1960-90	System GMM estimator with panel data	2%

			First differenced GMM estimator with instruments	4%
Miller and Upadhyay (2002)	83	1960-89	Fixed effects estimation of absolute convergence regression with cross-sectional and panel data	Conditional convergence of GDP per worker at the rate of 4% and conditional TFP convergence at the rate of 6%
Milanovic (2003)	17 rich	1870-1913	Fixed effects and IV technique	No convergence from 1817-1913 and strong convergence in 1913-38
Evans and Kim (2005)	17 Asian	1960-92	Dynamic random variable estimation of original Solow model	Convergence rate of 2%
Ismail (2008)	ASEAN 5	1960-2004	Pooled mean group estimation of original Solow model	Varying speed of convergence, 1.6% to 16.6%
<i>Analysis by Incorporating Additional Macroeconomic Variables in the Augmented Solow Growth model</i>				
Andres et al. (1996)	24 OECD	1960-90	Non-linear instrumental variables with panel data	2.4%
Sala-i-Martin (1996a)	110		LSDV method on panel data	2%
Barro (1998)	100		First difference method with panel data	4%
			Instrumental variable (IV) technique with panel data	2%
Barro (2003)	85	1965-95	IV technique with panel data	2.3%
Caselli et al. (1996)	97	1960-90	First differenced GMM with panel data	10%
Masron and Yusop (2008)	ASEAN-5	1980-2004	LSDV method on panel data	Evidence of conditional income convergence

samples, the estimation of the augmented Solow model with additional macroeconomic variables has shown higher values for the convergence coefficient. Moreover, the system GMM technique with the panel data is one of the most recent developments in the estimation of conditional β -convergence regressions.

In contrast to all these conditional convergence regressions based on either output per worker or output per capita, McQuinn and Whelan (2007) have focused on the conditional convergence pattern in the capital-output ratio in a panel data framework. Their study is based on the view that dynamics in capital-output ratio correctly reflects the conditional convergence of output per worker given the NGM. A much higher rate of conditional convergence of approximately 7% was reported for 96 world countries for the period 1950-2000. However, based on the assumption of NGM, convergence in capital-output ratio, and not in the TFP, is considered the key in the convergence of output per worker by McQuinn and Whelan (2007).

3.2.3. Intra-Country Regional Convergence

Although the analysis on cross-country income convergence has largely been in vogue, the phenomenon has been variously considered in the contexts of the regions of a country as well. There are numerous researches on the intra-country convergence from around the world utilizing both the cross-sectional and panel data methodologies. These studies have estimated either of the three to analyze the absolute or the conditional convergence; (i) the basic convergence regression, (ii) the Solow model in its basic or the augmented form or (iii) the income growth regression with additional macroeconomic variables. Absolute convergence regression is estimated utilizing the model by Barro and Sala-i-Martin (1990), while the NGM model by Mankiw et al. (1992) is mainly used to estimate the conditional convergence.

At the outset, Holtz-Eakin (1993) has analyzed conditional convergence based on the augmented Solow model for the US states. Contrary to the previous work by Barro and Sala-i-Martin (1990), the author has considered conditional convergence more appropriate even for within country analysis of convergence. Results have not only confirmed income convergence at a higher than typical 4%

rate, but have also validated the earlier finding of a negative relationship between the average labor productivity growth and the initial value of labor productivity. Similarly, Cashin (1995) and Persson (1997) found 1.2% and 4% rates of β -convergence for Australasia and Sweden respectively. The unusually large size of the estimated coefficient for the Swedish counties ought to be attributed to the adjustment in income on the basis of regional differences in the cost of living. The low Australasia and high Swedish estimate invite an interesting comparison with the findings by Kangasharju (1998) who reported a relatively moderate, 2%, rate of β -convergence for Finland over the period 1934-93. However, the analysis depicted an unstable trend of convergence during the sub-periods. Similar were the findings of Hofer and Worgotter (1997) regarding the conditional convergence of 84 districts of Austria. Compared to the 2% rate of inter-district conditional convergence, 8 regions of the country were converging at an absolute rate of 1% only.³¹

Revisiting the subject of convergence, Sala-i-Martin (1996a and 1996b) contributed a cluster of evidence on *conditional convergence II* by utilizing separate data sets for each; Japan, Canada, Spain, Germany, U.K, France and Italy. Analysis with a similar methodology generated dissimilar corresponding rates of convergence in the sample countries. Japan and the U.K. illustrated the highest rates of convergence among all, 3% and 2.9% respectively. These were followed by Canada with its rate of 2.4% while Spain conformed to the established figure of around 2%. Germany and Italy trailed with an estimate of 1.6%, followed by France with a lower rate of convergence, 1.5%. In contrast, Chatterji and Dewhurst (1996) have found no evidence of convergence across the counties and regions of Great Britain.³² Analyses based on multiple sub-periods have not only indicated convergence in few of the sub-periods but have confirmed a negative relationship between the country's overall economic performance and the tendency of convergence among regions. Contrary to the usual approach, Gundlach (1997) has utilized the open economy augmented form of NGM with cross sectional data and has confirmed both absolute and conditional β -convergence across Chinese regions. While, Austin and Schmidt (1998) have also

³¹Initially, the co-integration analysis between the region's and national per capita income has reported evidence of no divergence between the two.

³² As opposed to a conventional convergence regression, authors have used the final year per capita GDP difference between each region and London and the initial gap between these two as the dependent and independent variables in regression

confirmed conditional convergence for the 390 counties of the Great Plains of USA and Canada.

Findings by Ferreira (2000) and Azzoni (2001) have indicated higher conditional than absolute convergence for Brazil. The estimated coefficients in Ferreira (2000) have exhibited higher values for 1970s relative to that of later periods. However, Azzoni (2001) has reported no evidence of convergence prior to 1970 and an accelerated speed afterwards.³³ Further empirical validation for conditional β -convergence was provided by Nagaraj et al. (2000), Michelis et al. (2004) and Kim (2005) in their studies on regional convergence in India, Greece and South Korea respectively. According to their results, the Korean and Indian rates of income convergence were four and five times higher than those reported for Greek regions. However, as reported in Table 3.4, the underlying estimation techniques and time period of analysis in all three studies were different. Finally, a recent contribution to the empirics of convergence is by Solanko (2008), who has analyzed absolute and conditional β -convergence among Russian regions.

Together all of these results on intra-country convergence are confirming both the absolute and conditional convergence among various regions. Nevertheless, the convergence rates reported in Table 3.4 are predominantly around 2-3%. In this particular account, estimation of absolute rather than the conditional notion of convergence yielded lower rates of intra-country convergence. However, findings of all these intra-country convergence studies were questioned because these studies have not considered the spatial dependence between regions in a country. Therefore, in the presence of spatial error correlation, traditional convergence models are misspecified [Ray and Montouri (1999)]. This resulted in another cluster of studies on regional convergence utilizing the spatial econometrics techniques.

Initially, Ray and Montouri (1999) have utilized a spatial error model to analyze unconditional β -convergence among US regions. Two of the related studies are by Lall and Shalizi (2003) and Le Gallo et al. (2003). The former study has used spatial lag and spatial error models on Brazilian regions, while the spatial error

³³ Contrary to these findings, Verner and Tebaldi (2004) have reported no absolute convergence among the municipalities of Rio Grande do Norte in the Northeast of Brazil during 1970-1996.

Table 3.4. An Overview of Empirical Studies on Intra- Country Convergence

Table 3.4. An Overview of Empirical Studies on Intra- Country Convergence				
Author/Year	Nature of Cross Sectional Units	Data Period	Methodology	Key Conclusions on the rate of convergence
Holtz-Eakin (1993)	50 States of US	1973-86	OLS estimation of augmented Solow model with cross-sectional data	4%
Cashin (1995)	7 colonies of Australasia	1861-1991	Non-linear least squares and OLS estimation of basic convergence regression with cross-sectional data	1.2%
Persson (1997)	24 counties of Sweden	1911-93		4%
Kangasharju (1998)	88 small-scale sub regions of Finland	1934-93		2%
Hofer and Worgotter (1997)	84 districts of Austria	1961-89	OLS estimation of basic convergence regression with cross-sectional data	2%
Sala-i-Martin (1996a; 1996b)	47 prefectures of Japan	1955-87	Non-linear least squares estimation of basic convergence regression both with cross-sectional and panel data	3%
	10 provinces of Canada	1961-91		2.4%
	17 regions of Spain	1955-87		1.9%
	11 regions of Germany	1950-90		1.6%
	11 regions of U.K.			2.9%
	21 regions of France			1.5%
	20 regions of Italy			1.6%
Chatterji and Dewhurst (1996)	Counties and regions of Great Britain	1977-91	OLS estimation of final year per capita GDP difference between each region and London on its initial gap	No convergence
Gundlach (1997)	29 regions of China	1979-90	OLS estimation of basic convergence regression and augmented Solow model with cross-sectional data	2.7% rate of conditional convergence and 2% rate of absolute convergence
Austin and Schmidst (1998)	390 counties of Great Plains	1969-94	Panel data LSDV method on NGM with additional explanatory variables	2%
Ferreira (2000)	9 states of Brazil	1970-95	OLS estimation of basic convergence regression and augmented Solow model with	1% rate of absolute and 3% rate of conditional convergence

			cross-sectional data	
Azzoni (2001)	20 states of Brazil	1948-95	Non-linear least squares estimation of basic convergence regression with cross-sectional data; Dummies are incorporated for the regression of the conditional convergence	Absolute convergence at the rate of 0.7% and 1.3% rate for the conditional convergence
Michelis et al. (2004)	51 regions of Greece	1980-89	OLS estimation of both the basic convergence regression and the augmented Solow model using cross-sectional data	2% rate for each, the absolute and conditional convergence
Nagaraj et al. (2000)	17 states of India	1970-94	IV technique with panel data on NGM with additional explanatory variables	10%
Kim (2005)	13 regions of South Korea	1985-2002	Random coefficient model with panel data on augmented Solow model	8%
Solanko (2008)	76 Russian regions	1992-2005	Unconditional and conditional β -convergence with cross-sectional and panel data	5% for full sample and various rates otherwise
<i>Analysis based on Spatial Econometrics Techniques</i>				
Rey and Montouri (1999)	48 US states	1929-94	Absolute convergence using Spatial error model	1.8%
Lall and Shalizi (2003)	1372 Brazilian northeast municipalities	1985-97	Conditional convergence using spatial lag and spatial error model	Evidence of conditional β -convergence
Le Gallo et al. (2003)	138 EU NUTS I, II	1980-95	Absolute convergence using Spatial error model	1.4%
Fingleton and Lopez-Bazo (2006)	108 EU regions of 12 countries	1980-96	Estimation of Solow model with externalities across economies	2.4% to 3%
Kosfeld et al. (2006)	133 markets in west and 47 in East Germany	1992-2000	Spatial ARMA technique on augmented Solow model	smaller size of coefficients in West and high in East
Gyawali et al. (2008)	161 blocks in Alabama	1980-2000	Conditional convergence using Spatial lag model	1.1%

model was applied on the data of EU NUTS I, II in the later study. Another study on EU regions is conducted by Fingleton and Lopez-Bazo (2006), who have developed and applied a convergence equation with spatial externalities and have found a convergence rate between 2.4% to 3%.³⁴ The Spatial lag model estimation of the conditional β -convergence was also conducted by Gyawali et al. (2008). However, compared to the first-order spatial lag model applied in these studies, Kosfeld et al. (2006) have applied a spatial ARMA model to analyze income convergence in the unified Germany.

This substantial body of evidence sustaining the existence of convergence at various rates was mainly based on the augmented Solow model and panel data estimations. Alternatively, there is empirical literature on convergence implications of endogenous growth theory, also emphasizing a multiplicity of steady states and club convergence. Similarly, time-series methodology is considered an alternative method for the investigation of convergence; which is also accredited for originating the concept of stochastic convergence.

3.3. MULTIPLE STEADY STATES AND CONVERGENCE CLUBS

The phenomenon of multiple steady states was suggested by some of the new growth models asserting the concave shape of an aggregate production function in NGM as implausible. Azariadis and Drazen (1990) were of the view that *technological externalities with a 'threshold property'* induce multiple steady states equilibria via spillovers from various forms of capital and the process of human capital creation. In other words, threshold externalities through increasing social returns to scale in human capital generate multiple long-run steady states for different initial conditions, hence, rendering the conclusions more compatible with the endogenous growth theory. Similarly, Tamura (1991) has developed a model of endogenous growth incorporating spillover effects of human capital in investment technology. The latter induces per capita income convergence at the local level, while global equilibrium is

³⁴ Contrary to the positive evidence of convergence for the EU regions, Petrakos and Artelaris (2009) have concluded absolute divergence for the European regions while utilizing the weighted least squares approach.

believed to be characterized by a multiplicity of steady states. Discussing the causes of convergence clubs, while focusing on Research and development (R&D) and technology transfer, Howitt (2005, p. 150) wrote, “*the main driving force behind... the recent club convergence was the growth of a new set of scientific ideas and attitudes associated with the scientific revolution*”.

Taking the across cross-section heterogeneity of convergence coefficient and steady states into focus, Canova and Marcet (1995) have analyzed the issue within a Bayesian approach by estimating different steady states and speeds of adjustment for each country utilizing the data of per capita income of 17 Western European countries. Results indicated an average speed of conditional convergence of 11%. However, estimation of different steady states signified a huge gap between per capita income levels of countries which is indicative of persistent inequality in the overall income distribution. Moreover, initial conditions, and not the conditioning variables, were concluded as the major determinant of the cross-country income distribution.

Correspondingly, Maddala and Wu (2000) have also applied an empirical Bayesian approach through the shrinkage estimation method to study convergence among 98 countries. Parameter heterogeneity with panel data implied an average convergence rate of about 5% for the sample countries.³⁵ Consideration of multiple regimes for the subset of 17 European countries illustrated the diversity of convergence rates and steady states across sub-periods. The phenomenon of diverse convergence patterns was also endorsed by Den Haan (1995). However, the author attributed the underlying cause of this to multiple determinants of per capita income, specifically the role of productivity shocks. The finding of existence of diverse steady state paths and persistence of income gaps among world countries was also reported by Huang (2005); though, utilizing a flexible nonlinear approach developed by Hamilton (2001). The convergence hypothesis is validated only for countries with initial per capita income higher than \$1255. Similarly, Ho (2006) has also established positive evidence of income convergence for countries beyond a specific threshold level of income utilizing a dynamic panel data model with threshold effects.

³⁵Estimated convergence rate for the decade of 1950 was about 20% per year while the remaining two sub-periods of 1961-74 and 1975-90 have the lower annual convergence rates of 9.1% and 11.5% respectively.

Besides the analysis from a broad group of countries, issues of convergence consistent with a multiplicity of steady states is analyzed for regions of a country such as the study by De la Fuente (2002) who has analyzed the convergence hypothesis for Spanish regions. Findings have indicated a much faster rate of convergence towards very different steady states thus illuminating persistent regional disparities within a country. A further analysis of sources of convergence has confirmed the conditional convergence rate and the speed of technological diffusion equivalent to 12% and 22% respectively. Furthermore, the convergence accounting exercise has reported the percentage contributions by capital deepening, technological diffusion and educational investment as 40%, 33% and 25% respectively.

Compared to various other concepts of convergence, there are quite a few studies on empirical analysis of convergence with a multiplicity of steady states. Along with very high rates of local convergence illustrated in these studies, Table 3.5 also depicts the diversity of methodologies utilized in analyzing this subject. One of the noteworthy elements in convergence analyses with multiple equilibria was its emphasis on the configuration of convergence clubs. This guided the literature towards the concept of *club convergence* as an additional topic with that of the conditional convergence. The latter necessitates common structural parameters of countries irrespective of their initial conditions but the former also maintained identical initial conditions along with the similar structural characteristics of countries.

The terminology of convergence clubs was sourced from Baumol (1986), who has specifically emphasized its formation for the wealthiest group of countries using the cross-sectional data. Similarly, Chatterji (1992) has endorsed Baumol's findings of convergence clubs, though, each for the richest and the poorest groups of countries. The findings by Chatterji are based on a cubic equation with cross-sectional data estimation for a sample of 109 countries. A comprehensive empirical analysis on convergence with multiple sub groupings of the sample was extended by Durlauf and Johnson (1995). These groupings were based on both the initial values of per capita GDP and literacy rates. Initially, a sample of 92 countries over the period 1960-85 was divided into two broad groups. Estimated convergence rates

Table 3.5. Evidence on Convergence Involving a Multiplicity of Steady States and Club Convergence				
Author/Year	Nature of Cross-sectional units	Data Period	Methodology	Key Conclusions on the rate of conditional convergence
<i>Convergence with Multiple Steady States</i>				
Canova and Marcet (1995)	144 European regions	1980-92	Bayesian approach involving different steady states and speeds of adjustments for each cross-sectional unit	Average rate of 23%
	17 Western European countries			Average rate of 11%
Maddala and Wu (2000)	98 countries	1950-90	Empirical Bayesian approach through the Shrinkage estimation method	Average speed of 5%
De la Fuente (2002)	15 regions of Spain	1964-91	Non-Bayesian approach with regional dummies and panel data fixed effects method	12% rate
Huang (2005)	86 countries	1960-80	Flexible non-linear approach developed by Hamilton (2001)	Limited evidence of conditional convergence
Ho (2006)	48 US states	1969-2003	Panel threshold model	No convergence for poorest states and significant convergence for remaining groups
	121 countries	1960-2000		High convergence for high income countries and no convergence for the poorest group
Bartkowska and Riedl (2012)	206 European NUTS2 regions	1990-2002	Ordered logit model	Six convergence clubs
<i>Club Convergence</i>				
Chatterji (1992)	109 countries	1960-85	OLS estimation of cubic specification for income gap from USA in final and initial years	Convergence club for the richest and the poorest group
Durlauf and Johnson (1995)	92 countries		Classification and Regression Tree Analysis (CART) and OLS estimation of augmented Solow model	No Convergences in high output economies but in other three groups defined by CART
Feve and Le-Pen (2000)	92 countries	1960-89	Switching regression approach	Convergence among the rich group but not among the poor group
Canova (2004)	144 European units	1980-92	Predictive density approach	Four convergence clubs
	21 OECD countries	1951-85		Two convergence clubs

were approximately 4% both in the high literacy/high output group and low literacy/low output group, which is higher than the convergence estimate of single sample by Mankiw et al. (1992).³⁶ Later, a regression tree analysis is also utilized for group identification and subsequently, a growth equation is separately estimated for each of the four subgroups identified by this technique. A great deal of difference is reported between the values of the convergence coefficients; from a high and significant one for the poorest group to a very small and insignificant one for the rich economies. Recently, Bartkowska and Riedl (2012) have emphasized the role of human capital and initial income as the key factors in establishing the convergence clubs of European regions.

Adhering to the phenomenon of convergence clubs, further analysis of the topic was furnished by Feve and Le-Pen (2000) who have applied the '*switching regression approach with imperfect sample separation information*' while, assuming two convergence clubs for 92 world countries. After endogenous determination of members of clubs through this technique, conditional convergence is estimated for each group and is confirmed for the rich group at the established rate of 2%. But no significant convergence is illustrated for the poor group of countries. However, this approach has the limitation of just two convergence clubs and instead, Canova (2004) has utilized the predictive density approach for the identification of convergence clubs.³⁷ Application of this methodology on 144 European units has validated the heterogeneity in income per capita and the consequent formation of four convergence clubs. Likewise, 21 OECD countries are also clustering around 2 clubs with the poor being below the average of the distribution.

In spite of the utilization of dissimilar estimation techniques, a common conclusion emerging from Table 3.5 is the confirmation for the existence of convergence clubs in both the developed and the broad groups of countries. Nevertheless, Galor (1996) has an entirely opposite outlook regarding the distinction between the conditional and the club convergence. The author viewed the club

³⁶Authors have termed group based convergence of countries as *local convergence* while the terminology of *global convergence* is used to refer to the convergence of all countries in the world [see, Durlauf and Johnson (1992)].

³⁷ Additional to the classification of groups, the approach also determines the location of the break points and ordering of the units in a cross-sectional space. Furthermore, it is also used to estimate the distribution specific parameters of the model as well.

convergence compatible with both the conditional convergence hypothesis and the NGM. The underlying premise for the argument is that the Solow model can be typified with multiple steady states in the presence of heterogeneous characteristics of economic agents. Therefore, club convergence becomes plausible in the same model of conditional convergence. Moreover, augmentation of the growth model with the human capital, fertility rate and income distribution in the presence of technological progress and capital mobility further enhances the likelihood of club convergence. In the same way, Islam (2003a, p. 323) also assert that “*Despite the conceptual distinction, it is not easy to distinguish ‘club convergence’ from ‘conditional convergence’ empirically*”.

Similar to that of conditional convergence, the literature on club convergence also involves both the cross-sectional and time-series methodologies. The studies on convergence clubs involving time-series methodology will be discussed in the next part.

3.4. TIME-SERIES NOTIONS OF CONVERGENCE

The preliminary concept of time-series convergence namely stochastic convergence emerged alongside the empirics of convergence entailing multiplicity of steady states. Since then, numerous studies have analyzed the topic utilizing several notions and various techniques pertaining to time-series analysis. These studies can be broadly categorized into three clusters on the basis of their methodology. The first set comprised of researches sourced from bivariate unit-root tests. The second of these are based on a variety of panel data unit root and stationarity tests; while the remaining studies are characterized with multiple techniques such as Kalman filter, co-integration and the stochastic growth model.

Bernard and Durlauf (1991) established the tradition of incorporating time-series methodology in the empirics of convergence. Adhering to the time series properties of per capita GDP of countries, Bernard and Durlauf (1991 & 1995) have considered the unit root properties of the series.³⁸ Their consideration of stochastic

³⁸ In another study, authors have affirmed the theoretical and empirical superiority of time series methodology over the cross sectional data techniques for the study of long run convergence [see Bernard and Durlauf (1996)].

trends in income series ascertained the phenomenon of *stochastic convergence* in per capita output. According to the concept, unit roots in without trend log per capita GDP of two countries reflect the presence of a common stochastic trend. Therefore, absolute convergence warrants the difference of these two stochastic trend series to be a level stationary process. However, their co-integration is sometimes indicative of divergence though it also entails some interrelationship between the shocks taking place in each country. Bivariate convergence is examined through unit root tests on paired deviations of income for 15 OECD countries.³⁹ Long-run movements of output, their deviations and inter-relationships failed to validate convergence among the aggregate sample; nonetheless, there was some evidence of stochastic convergence among European members of the sample.

Applying the parallel time-series technique, Jones (2002) has also concluded rare evidence of convergence among the Economic Community of West African States (ECOWAS). Analogous affirmation of no convergence was further reported by Asteriou et al. (2002) and McGuinness and Sheehan (1998) for 13 regions of each of Greece and U.K. respectively.⁴⁰ Bivariate augmented Dickey Fuller (ADF) tests have confirmed convergence only for 11 in 55 pairs thus rendering divergence as a more plausible indication for the U.K. While, no convergence was reported for the Greek regions.

A comprehensive pair-wise unit root analysis for both output and growth convergence was contributed by Pesaran (2007) focusing on output series of each of 56, 99 and 101 countries over the periods 1950-2000, 1961-2000 and 1971-2000 respectively. Unit root and trending properties were investigated for all possible pairs, $N(N-1)/2$, of log real per capita output gaps utilizing ADF and KPSS unit root tests. Results have corroborated little output convergence in the world. Nevertheless, there is some evidence for convergence in various subsamples thus validating the existence of convergence clubs. Contrary to the results of output convergence, the

³⁹ Besides these, spectral density and distribution functions of the deviations and application of a multivariate Johansen co-integration test on a variety of groups within the sample were the additional components of the analysis.

⁴⁰ Asteriou et al. (2002) have also utilized multivariate Johansen co-integration technique and confirmed the prevalence of economic dualism for Greece.

growth convergence hypothesis is validated for 72% of the pairs but, with considerable geographic dissimilarities.⁴¹

Alternative notions, though based on unit-root tests of income deviations, for both stochastic and β -convergence were extended by Carlino and Mills (1993), while rendering both of these types of convergence essential to illustrate the overtime reduction in income differentials. According to the definition, stochastic convergence necessitates trend stationarity in the log of per capita income of a country or region relative to that of the entire group. While, statistical significance together with the opposite signs for point estimates of the intercept and trend coefficients in a deterministic trend function signify β -convergence. The methodology was applied on the data for 8 US regions and the results were based on traditional ADF unit root tests while incorporating an exogenously determined trend break as suggested by Perron (1989). Three regions in a total of 8 have shown both the stochastic and β -convergence while the remaining regions reported otherwise.

Owing to their dissatisfaction regarding weak evidence of convergence for the USA in the above analysis, Loewy and Papell (1996) revised the methodology for stochastic convergence. They have incorporated an endogenous trend break in unit root tests by applying the sequential additive outlier method along with the innovative outlier method also utilized in the earlier study. As an outcome, a much stronger evidence for stochastic convergence was realized with this substantiation from 7 in 8 regions.⁴² Later, Li and Papell (1999) also applied the methodology of sequential unit root tests with an endogenous trend break on an OECD sample. A highlight of the study was the introduction of the term *deterministic convergence* and its respective differentiation from the already established concept of stochastic convergence. According to the authors, level stationarity of the log of relative output is indicative of deterministic convergence as was earlier defined by Bernard and

⁴¹ For a recent application of this methodology on European regions, see Pen (2011).

⁴² However, the study did not address the methodology of β -convergence for revision, which was later acknowledged by Tomljanovich and Vogelsang (2002). Maintaining the similar notion, direct estimation of intercept and trend coefficients with OLS method was undertaken with both the known and unknown trend break models. All the eight regions have validated the evidence for convergence. Contrary to the findings of Loewy and Papell (1996) regarding stochastic convergence, evidence for β -convergence is stronger with a known break date compared to the model incorporating an endogenous trend break. However, both of the results together have confirmed income convergence in the USA.

Durlauf (1995). On the other hand, the concept of time-series convergence by Carlino and Mills (1993) meant stochastic convergence which requires log of relative output to be trend stationary. The former is considered a robust notion of time-series convergence as compared to the latter one. Results have confirmed that the inclusion of an endogenous trend break has reinforced the evidence for both of these convergence concepts as 14 and 10 in a total of 16 countries have confirmed stochastic and deterministic convergence respectively. The stochastic convergence among the Chinese regions was also analyzed using the innovative outlier method of the sequential unit root test by Zhang et al. (2001). The findings have reported convergence of East and West regions towards their own specific steady states but there was no evidence of convergence for the Central region.⁴³

In another study, Oxley and Greasley (1995) have used the ADF test incorporating an endogenous structural break to investigate pair-wise convergence between the USA, U.K. and Australia. However, maintaining the similar definitions, authors have used different terminologies, i.e. catching-up and long run convergence for stochastic and deterministic convergence respectively. Results have validated long-run income convergence between Australia and U.K. alongside a catching-up tendency between U.K. and USA and Australia and USA. Afterwards, in a study for an OECD sample, the authors have also identified bivariate long run convergence between France and Italy; Belgium and the Netherlands; Australia and U.K. and Sweden and Denmark [Greasley and Oxley (1997)]. Continuing with the topic, Oxley and Greasley (1999) have applied a similar methodology for the analysis of stochastic convergence among the Nordic countries. Results have identified long-run convergence between Sweden and Denmark and a catching up tendency between Sweden and Finland whilst neither of the convergences is reported for the Norway.

Another analysis of stochastic convergence with ADF unit root tests for 16 industrialized countries was done by St. Aubyn (1999). The per capita GDP of the USA was used as a benchmark for the test of relative per capita GDP for each country. In addition, dummy variables were incorporated to take account of the structural breaks. The hypothesis of no convergence was rejected for 11 countries

⁴³ Methodology of trend break has identified the economic reforms and the Cultural Revolution as the most significant breaks for the relative per capita income

confirming catch-up among the OECD countries. Moreover, the application of a different technique namely, the Kalman filter has further validated convergence among the full sample of 16 industrialized countries along with a stronger substantiation for the post WWII period. However, St. Aubyn termed both these pieces of evidence as conditional convergence while asserting differences in steady state income levels of countries. This was verified through the estimation of steady states and speeds of convergence for each of the G-7 countries. Resultantly, the hypothesis maintaining equality of steady states across countries was not rejected, but speeds of convergence have exhibited huge variations ranging from a low 3% to as high as 32%.

The Kalman filter technique is also used by Datta (2003) for the recursive estimation of regressions with time varying parameters to study the transitional dynamics and convergence of 15 OECD countries using the data from 1950-98. Earlier, application of the pair-wise co-integration technique on the sample has shown little convergence. But the Kalman filter methodology has signified stronger catch-up among the sample countries under the assumption that countries are farther from their steady states.

Likewise, Lim and McAleer (2004) have utilized the Kalman filter, Johansen pair co-integration and pair-wise unit root tests to analyze the stochastic and deterministic convergence among ASEAN-5 and between ASEAN-5 and USA. ADF tests validated divergence between all possible pairs of ASEAN-5 countries and the USA except for the pairs of Singapore and Thailand and Malaysia and the Philippines. At the same time, no long run co-integrating relationship was reported between each of the ASEAN-5 countries and the USA, but, Singapore illustrated such a relationship both with Malaysia and Indonesia. In contrast, the Kalman filter technique confirmed convergence between Singapore and a sub-set of the member countries along with the former's convergence towards the USA.⁴⁴ Moreover, analysis of technological catch-up between each of the ASEAN-5 countries and USA has indicated significant results of catch-up only for Singapore.

⁴⁴ St. Aubyn (1999) termed such evidence of convergence as *limited convergence*, in which a subset of countries in a group, but not all, demonstrated a tendency towards it.

Dawson and Sen (2007) have extended the analysis both in its spatial and temporal dimensions by considering a broader cluster of 29 countries with a century long data from 1900-2001. The ADF unit root test and mixed model test with trend-break stationary alternatives have confirmed stochastic convergence for 21 countries while rendering WW-II as the major source of a trend break.⁴⁵ In the second step of their analysis, the authors have analyzed β -convergence by estimating intercept and trend coefficients in the *trend test* of convergence. The results have shown that 16 of the 21 sample countries are presently converging either in the first or the second half of the whole period under consideration. Moreover, group based analysis of convergence has affirmed the phenomenon of convergence clubs for the sample.

However, Strazicich et al. (2004) have argued that the methodology of univariate unit root tests incorporating an endogenous trend break may cause spurious rejection of a null hypothesis of no unit root. Alternatively, a more comprehensive unit root test, namely the minimum Lagrange multiplier (LM) test was applied on the log of relative real per capita GDP of countries. The method encompasses two structural breaks in level and trend along with their endogenous determination from the data. Ten of the 15 OECD sample countries have indicated stochastic convergence across 1870-1994, while in the post WWII period, this number increased to 12. Two of the other applications of the minimum LM unit root test are by Galvao and Reis Gomes (2007) and Dawson and Strazicich (2010). The former has concluded β -convergence for 12 of 15 Latin American countries. While, results of the latter have confirmed stochastic convergence with two structural breaks for 22 of 29 world countries while, Australia exhibited stochastic convergence with one structural break only.

Together with a cluster of evidence on stochastic, deterministic and β -convergence utilizing bi-variate unit root tests, a number of studies conducted on time-series convergence are based on the panel data unit root and stationarity tests. An example is the preliminary contribution by Evans and Karras (1996a), who have concluded strong conditional stochastic convergence among 48 US states and 54

⁴⁵The mixed model test takes the form: $y_t = \mu_0 + \mu_1 DU_t(T_b) + \mu_2 t + \mu_3 DT_t(T_b) + \alpha y_{t-1} + e_t$. Break date is T_b , while $DU_t(T_b)$ and $DT_t(T_b)$ are the intercept-break and slope-break dummies respectively.

countries of the world. The authors have applied the panel unit root method developed by Levin and Lin (1993) on per capita income deviations of countries.⁴⁶ This panel unit root methodology was also applied by Evans and Karras (1996b) to study the absolute convergence among US states, because according to the authors absolute convergence notion is only practical for within country analysis. A distinguishing aspect of this study was the separate focus on determinants of output per worker, namely technology, capital share and rental rate. The stationary pattern of the technology variable confirmed convergence among states channeled through access to technical knowledge; though results failed to endorse the absolute convergence hypothesis.⁴⁷

A number of panel unit-root tests were also applied by Fleissig and Strauss (2001) on the data of real per capita GDP of 15 OECD countries and its European sub-sample.⁴⁸ Owing to the existence of a structural break prior to 1948, a sub period from 1948-87 was also analyzed. Results reported no evidence of stochastic convergence for the whole period, while the opposite is significantly valid for the post war period. Moreover, the estimated speeds of adjustment ranged between 4% to 8% and 6% to 9% for the OECD and European samples respectively. Also, employing the panel unit root test by Im et al. (1997) and panel co-integration test by McCoskey-Kao (1999), McCoskey (2002) has studied stochastic convergence in Sub-Saharan African countries. In addition to the income variables, the study has also investigated convergence in government share of GDP, capital per worker, openness of economy and standard of living. Minor indication of a long-run relationship between income variables was obtained from co-integration tests. Alongside, though confined to a few countries, there were also some catch-up tendencies in other variables thus confirming no overall convergence in the region. In contrast, Kim (2001) reported significant evidence of stochastic income convergence

⁴⁶ Monte Carlo simulations verified more estimation power for the panel unit root test as compared to that of bivariate unit root tests.

⁴⁷ Contrary to these findings, in a further study, Evans (1997) has validated a convergence rate of 15.5% among 48 states of USA by formulating and applying an alternative time-series approach. Similarly, the method, when applied to a sample of 48 countries, has reported an estimated convergence rate of 5.9%.

⁴⁸ Authors have alternatively employed Abuaf and Jorian SUR procedure, Im, Pesaran and Shin Test and Fisher P_λ test of Maddala and Wu for the investigation of unit-root.

among 17 Asian countries utilizing panel unit root tests by Levin and Lin (1993) and Im et al. (1997).

Cheung and Pascual (2004) have studied output convergence of G7 countries towards the USA, over two different time periods; 1950-92 and 1885-1994. Univariate ADF test and the panel data LM and multivariate augmented Dickey Fuller (MADF) unit root tests do not establish any evidence for convergence in the short time span, while the Breuer et al. SURADF test confirms convergence only for Germany. However, application of the panel stationarity test proposed by Choi and Ahn overturned the findings on stochastic convergence. Contrary to the results of post WWII data, the longer data set provides strong evidence of convergence.

Absolute and conditional stochastic convergence based on the augmented form of panel unit-root methodology was also analyzed by Guetat and Serranito (2007) for countries in the Middle East and North Africa (MENA). Two broad samples comprising 11 countries over 1960-90 and 9 countries with the time period 1960-2000 alongside their multiple sub groupings, were considered in the analysis. Except for a few of the sub-samples, both types of stochastic convergence are validated for each of the broad groups while incorporation of an endogenous trend break further strengthened the tendency towards catch-up. The authors have also corroborated the presence of convergence clubs in the MENA region.

Romero-Avila (2009) has used a recent panel stationarity test introduced by Carron-Silvestre et al. (2005) to study the convergence among 19 OECD countries for the period 1870-2003. This panel stationarity test incorporates multiple endogenous breaks and slope shifts and is also adjusted for general forms of cross sectional dependence and finite sample bias. In contrast with earlier results, the underlying method has validated strong stochastic as well as conditional β -convergence among the sample countries in the 20th century. However, only 3 of the total sample countries have reported deterministic convergence affirming that the reduction in income differentials is still continuing. Based on a similar methodology, a corresponding conclusion of significant stochastic convergence was also illustrated by Carron-Silvestre and German-Soto (2009) in an analysis of 32 Mexican regions. The study also confirmed moderate but inconsistent evidence of β -convergence for the whole period and a robust evidence for β -convergence in the decade of 1980s.

Also, Evans and Kim (2011) have shown stochastic convergence among 13 Asian countries utilizing the panel stationarity test by Carron-Silvestre et al. (2005).

Owing to the time-series focus of convergence, a new development in growth empirics was the conceptualization of the stochastic Solow growth model and the estimation of convergence within this framework. Attributed to Lee et al. (1997), the study has analyzed the per capita output growth for 102 countries while utilizing the heterogeneous panel data by incorporating the country specific technological growth rates. The authors have indicated considerable asymptotic bias in traditional estimates of β -convergence; which has been reflected through the substantially higher estimates for the speed of convergence in the sample.⁴⁹

Criticizing the pairwise unit root and co-integration approach of convergence, Linden (2002) has proposed an alternative framework of non-stationary and non-linear time-series convergence based on the linear deterministic trend model of the form:

$$\ln(d_{j,t}) = \beta + \alpha t + \varepsilon_t \quad (3.3)$$

Where $d_{j,t}$ is the difference between the per capita income of USA and that of the sample country. This equation was estimated using the OLS technique for 15 OECD countries over the years 1946-97. Results have confirmed a significant catch-up tendency in majority of the European OECD countries and Japan but for some countries the process has overturned towards that of divergence since 1980s.

Nahar and Inder (2002) have also criticized the time-series methodology suggested by Bernard and Durlauf (1995). Alternatively, Nahar and Inder (2002) have estimated trend regressions for both, the squared demeaned output and the output gap from the USA and considered the resultant average slopes for the test of absolute convergence.⁵⁰ All the 22 OECD sample countries have exhibited high convergence towards their average over the period 1950-98 with the exception of Germany, Iceland and Norway. While in the output gap regressions, Switzerland and New Zealand were the only two countries failing to catch-up towards the USA. A

⁴⁹ However, because of the methodological ambiguity in the analysis, authors rendered these estimates and specifically their interpretation as implausible.

⁵⁰ Authors were of the view that near zero values of the squared demeaned output indicate income convergence, which can alternatively be described by the negative sign of the time derivative of squared demeaned output.

further extension of this analysis was furnished by Bentzen (2005) who has incorporated the QLR-test of structural stability in the regression equation entailing convergence towards the USA. This test was applied to detect shifts in the rate of convergence across the sample countries. Findings indicated differences in the timings of catch-up across countries, thus emphasizing the role of country-specific factors in the convergence process. Moreover, analysis pertaining to two equal sub-periods has mainly illustrated a higher speed of catch-up during the first half as compared to the later one.

The fractional integration approach is still another variant of the time series techniques in convergence empirics. Contributed by Cunado et al. (2003), the method was applied to the data of Australia, Canada, Japan and U.K for the investigation of real convergence towards the USA. The real convergence is defined as the mean reversion in per capita output differences among countries. Both the parametric and non-parametric procedures have been utilized with a century long data of per capita real GDP beginning with 1901. Findings illustrated strong evidence of convergence for Australia and Canada along with some evidence for U.K.; yet the study did not endorse real convergence hypothesis for Japan.

A closer look at the summary of all these studies in Table 3.6 confirms fair amount of evidence for cross-country and intra-country income convergence in a time-series framework. This substantiation becomes stronger by utilizing the advanced forms of the unit-root tests specifically with the incorporation of the trend breaks in the data. Moreover, in contrast to the cross-sectional and panel data estimations of conditional convergence, the analysis on time-series notions of convergence entails longer and updated data periods. Furthermore, there are studies on club convergence which have utilized the time-series framework, which will be discussed in the following.

Initially, Ben-David (1994) has endorsed the formation of convergence clubs for 113 economies. After ranking the countries into various income groups, his study considered the concept of stochastic convergence through the application of the ADF test on the log of per capita income differentials. Both the combined and semi combined broad samples exhibited divergence; however, analyses for the 8 sub-samples of income have validated the existence of convergence clubs for the richest

Table 3.6. Time-Series Analysis of Convergence				
Author/Year	Nature of Cross-sectional units	Data Period	Specific Notion of convergence/Methodology	Key Conclusions on the convergence
Bernard and Durlauf (1991 & 1995)	15 OECD countries	1900-87	Stochastic convergence/ Pair-wise co-integration and ADF unit-root tests on paired income deviations	No convergence
McGuinness and Sheehan (1998)	13 regions of U.K.	1971-96		Very little evidence
Jones (2002)	15 countries in ECOWAS	1960-90		Little evidence (20% of total deviations)
Asteriou et al. (2002)	13 regions of Greece	1971-96		No convergence
Pesaran (2007)	56 countries	1950-2000	Stochastic convergence/ADF and KPSS unit root tests on all possible paired income deviations	Little evidence of convergence in aggregate sample but some evidence in sub-samples
	99 countries	1961-2000		
	101 countries	1971-2000		
Carlino and Mills (1993)	8 regions of US	1929-90	Stochastic and β -convergence/ADF unit root test incorporating exogenous trend break using innovative outlier method	Validation for 3 regions
Loewy and Papell (1996)			Stochastic and β -convergence/ ADF unit root test incorporating endogenous trend break using sequential additive outlier method	Validation for 7 regions
Li and Papell (1999)	16 OECD countries	1900-89	Stochastic and Deterministic convergence/ ADF unit root test by incorporating endogenous trend break using sequential additive outlier method	14 & 10 countries have confirmed stochastic and deterministic respectively
Oxley and Greasley (1995)	USA, UK and Australia	1870-1992	Catching-up tendency and Long-run Convergence/ bi-variate ADF unit root test by incorporating endogenous trend break using sequential additive outlier method	Long-run convergence between Australia and U.K. and Catching-up between U.K. & USA. and Australia & USA.
Greasley and Oxely (1997)	OECD countries	1900-87		Long-run convergence between France & Italy; Belgium & Netherlands; Australia & U.K. and Sweden & Denmark
Oxley and Greasley (1999)	5 Nordic countries			Long-run convergence between Sweden & Denmark; Catching-up between Sweden & Finland
St. Aubyn (1999)	16 industrialized countries	1890-1990	Stochastic convergence/Kalman filter and ADF unit root test with dummy variables	Confirmation for full sample

Zhang et al. (2001)	3 Chinese regions	1952-97	Stochastic convergence/ ADF unit root test by incorporating endogenous trend break using sequential additive outlier method	Validation for 2 regions
Datta (2003)	15 OECD countries	1950-98	Catching-up tendency/ Kalman filter	Strong tendency of catch-up
Lim and McAleer (2004)	5 founding member countries of ASEAN and USA	1965-92	Stochastic and Deterministic convergence/ ADF unit root test and Kalman filter	Confirmed for Singapore with other member countries and towards USA as well
Dawson and Sen (2007)	29 countries	1900-2001	Stochastic and β -convergence/ADF and mixed model unit root test by incorporating exogenous trend break using innovative outlier method	Stochastic convergence for 21 countries while β -convergence is confirmed for 16
Strazicich et al. (2004)	15 OECD countries	1870-1994	Stochastic convergence/Minimum Lagrange Multiplier (LM) unit root test	Validated for 10 countries
Galvao and Reis Gomes (2007)	19 Latin American countries	1951-99	Stochastic and β -convergence/Minimum Lagrange Multiplier (LM) unit root test	15 countries have shown stochastic convergence while β -convergence is confirmed by 12
Dawson and Strazicich (2010)	29 countries	1900-2001	Stochastic convergence/Minimum Lagrange Multiplier (LM) unit root test	Stochastic convergence for 22 countries
Evans and Karras (1996a)	48 states of USA	1929-91	Conditional stochastic convergence/Panel unit root test by Levin and Lin	Validated convergence for both of the samples
	54 countries	1950-90		
Evans and Karras (1996b)	48 states of USA	1970-86		No absolute convergence but validated conditional convergence
Fleissig and Strauss (2001)	15 OECD countries	1900-87	Stochastic convergence/Panel unit root tests	No convergence for the whole period but for the post-war period
Kim (2001)	17 Asian countries	1960-92		Strong stochastic convergence
Kalra and Sodsriwiboon (2010)	15 major states of India	1960-2003		Divergence in the full sample but convergence in sub-samples
Cheung and Pascual (2004)	G7 countries	1950-92	Stochastic convergence/Panel data LM and MADF unit root tests & Panel stationarity test	Little evidence
		1885-94		Strong evidence
Guetat and Serranito (2007)	11 countries of MENA	1960-90	Absolute and Conditional stochastic convergence/Panel unit root tests with endogenous trend breaks	Both of the convergences are validated for the broad samples
	9 countries of MENA	1960-2000		
Romero-Avila (2009)	19 OECD countries	1870-2003	Stochastic and β -convergence/Panel stationarity test by	Validation of strong evidence for both types

			Carron-Silvestre et al. (2005)	of convergence
Carron-Silvestre and German-Soto (2009)	32 regions of Mexico	1940-2001		Significant stochastic but moderate β -convergence
Evans and Kim (2011)	13 Asian countries	1960-2007		Significant stochastic convergence
McCoskey (2002)	37 countries of Sub-Saharan Africa	1960-90	Stochastic convergence/Im et al. panel unit root test and McCoskey-Kao (1999) panel co-integration test	No overall convergence
Lee et al. (1997)	102 countries	1960-89	Stochastic convergence/Stochastic form of Solow growth based using heterogeneous panel data	Very strong
Linden (2002)	15 OECD countries	1946-97	Non-stationary and non-linear time-series convergence/Linear deterministic trend model	Significant catch-up tendency for majority of the countries
Nahar and Inder (2002)	22 OECD countries	1950-98	Absolute Stochastic convergence/Regression of Squared demeaned output on time trend	High convergence in majority of the countries
Bentzen (2005)			Absolute Stochastic convergence/Regression of Squared demeaned output on time trend while incorporating QLR-test of structural stability	High convergence but with differences in the timings of catch-up
Cunado et al. (2003)	Australia, Canada, Japan and the U.K.	1901-2000	Stochastic convergence/Fractional integration approach	Strong for Australia and Canada and some evidence for U.K.
Club Convergence				
Ben-David (1994)	113 market economies		Stochastic convergence on various sub-groupings of sample using ADF unit root test	Convergence clubs for the richest and the poorest group of countries
Bianchi (1997)	119 countries	1970-89	Bootstrap multimodality and density functions	Convergence clubs each for rich and the poor group
Hobijn and Franses (2000)	112 countries	1960-89	Stochastic convergence in country groups identified using cluster algorithm technique	Identification of convergence clubs and confirmation of perfect convergence for low income group
	15 OECD countries	1900-87		Four to five convergence clubs
Su (2003)	15 OECD countries	1900-87 1885-1994		
Li (1999)		1960-89	Stochastic convergence on various sub-groupings of sample using ADF and KPSS unit root tests	Convergence club for the wealthiest group but divergence among the poor group
Alexiadis and Tomkins (2004).	13 regions of Greece	1970-2000	Based on stochastic convergence by regression of squared demeaned output on time trend	Identification of convergence clubs
De-Siano and D'Uva (2006)	European region		Stochastic convergence using ADF and KPSS unit root tests on sub-groupings generated by CART	Convergence club for the wealthiest group

and poorest groups of countries. Contrary to the earlier findings, multiple segregations of the sample revealed more frequent evidence of convergence in the poorest group in contrast with the wealthiest one. However, Li (1999) has confirmed otherwise, in his application of ADF and KPSS unit root tests to the similar data of world countries. Results have validated the prevalent view of divergence in the broad sample, while, the middle income group has shown some evidence for a convergence club.

Incorporating the time-series techniques, specifically the approach developed by Nahar and Inder (2002), an analysis on stochastic convergence and convergence clubs for 13 Greek regions is contributed by Alexiadis and Tomkins (2004). The results show no consistent pattern of convergence across all regions alongside the confirmation for the existence of convergence clubs for some regions. In another study on club convergence for 112 world and 15 OECD countries by Hobijn and Franses (2000), the identification of convergence clubs was based on a type of cluster algorithm. The analysis examined: (i) asymptotically perfect convergence, (ii) asymptotically relative convergence and (iii) convergence of growth rates. Concepts of asymptotically perfect and asymptotically relative convergence exactly correspond to previously defined deterministic and stochastic convergence respectively. The growth convergence is defined as the zero mean stationarity of the $\Delta d_{(i,j)t}$ and $d_{(i,j)t}$ is the income difference between countries i and j . The results report 63 asymptotically perfect convergence clubs and 42 asymptotically relative convergence clubs for the sample of 112 countries, while for the OECD sample, the corresponding numbers are 9 and 7 respectively. The overall results for convergence clubs confirm more pervasiveness of the perfect convergence in the low income countries as compared to the group of industrialized countries. Furthermore, the phenomenon of growth convergence is most prevalent of all three types of convergences considered in the analysis. Afterwards, Su (2003) has endorsed the similar results by corroborating the formation of 4-5 convergence clubs with 2-4 members each, for the sample of 15 OECD countries over two separate periods ranging from 1990-87 and 1885-94.

De-Siano and D'Uva (2006) have focused on the arbitrariness involved in various criteria of groupings for the configuration of a club and as an alternative,

have used CART analysis for the categorization of the European region. Stochastic convergence results within four groups, identified by CART, conformed to the prior evidence in favor of convergence for the wealthiest region; although, weak convergence was observed within the other three strata.

In all its manifestations, either utilizing cross sectional, panel or time-series data; per capita income convergence through the β -convergence formulations specifically in *conditional* form has gathered enormous substantiation from the empirical literature. Nevertheless, β -convergence is still considered insufficient to exemplify the true reduction in income differentials across cross-sections. Consequently, σ -convergence is also rendered as an appropriate method for investigating per capita income convergence in the world [Friedman (1992)].

3.5. σ -CONVERGENCE

The trend in the cross-sectional dispersion of per capita income across various cross-sections is termed as σ -convergence and is also rendered a significant indicator of long-run income convergence. Though the concepts of β and σ convergences differ in their evaluation, but analogous to β -convergence the analysis on σ -convergence also encompasses both the cross-sectional and time-series methodologies. This is the basis for dividing this particular part into various sections. First section, 3.5.1, will present the studies on the cross-sectional analysis of σ -convergence. Researches pertaining to both the distributional approach and the time-series methodology will be considered in the second section (3.5.2).

3.5.1. σ -Convergence as Cross-sectional Dispersion of Income

The concept of σ -convergence predates that of β -convergence. Primarily, Streissler (1979) has considered the trend of cross-sectional variance over time. However, the cross-sectional variance is primarily used to study the diffusion process of economic growth among 93 countries and its various sub samples. Variances of indices incorporating the nominal and real GDP per capita for the industrialized and relatively developed countries have shown an overall decreasing pattern till 1972 but

this declining trend was reversed in 1973. The regression of variances on the time trend have validated the catching-up tendency of the developing countries towards the already developed group of the sample.

Subsequently, Baumol (1986) and Abramovitz (1986), along with furnishing the primary evidence for β -convergence, have also corroborated strong convergence of the second kind among 16 industrialized countries. However, both of the studies have reported a reversal in this declining trend for some years around WWII. Similar conclusions of strong convergence were also validated by Dowrick and Nguyen (1989) utilizing the constant relative per capita GDP data of 24 OECD countries. The dispersion among countries has illustrated a sharp decline in the period 1950-73 but this declining trend slowed down in the later years of the sample.

All the aforementioned initial deliberations on cross-national dispersion of income have not formally contemplated on the idea of ' σ -convergence'. Based on the parallel methodology of income variation over time, Barro and Sala-i-Martin (1990) have introduced this notion in the convergence literature. The derivation of a causality relationship between the β and σ convergence has exemplified that the former causes the latter, but that the former is only a necessary and not a sufficient condition for the prevalence of the latter. Empirical analyses have confirmed σ -convergence among US states; while, the standard deviation of log per capita GDP has increased for the broad sample of 98 countries. Moreover, for the OECD group, findings are in complete conformity with those of Dowrick and Nguyen (1989) discussed previously.

Continuing with the US sample of 47 states spanning over a century long data, Barro and Sala-i-Martin (1990) have shown an overall diminution in income dispersion for the whole period apart from the 1930s and the mid-1970s.⁵¹ The authors have suggested agricultural and oil shocks as respective underlying causes of these exceptions. Region based analysis has illustrated a sharp and smooth decline in dispersion for the western region; however, for the other three regions the overall decreasing trend was fluctuating. Corresponding to σ -convergence confirmation for

⁵¹ Parallel conclusions of reduced income dispersion for USA states were also confirmed by Holtz-Eakin (1993). Author calculated coefficient of variation of output per worker for the period 1973-1986.

USA was the evidence of seven Australasian regions analyzed by Cashin (1995). The results show a reduction in the standard deviation of real per capita income over the full study period; although, numerous sub-periods of σ divergence were also reported.

Similarly, Persson (1997), Kangasharju (1998) and Michelis et al. (2004) have confirmed σ -convergence among 24 Swedish counties, 88 Finnish small-scale sub-regions and 51 Greek regions respectively. However, the Swedish counties have exhibited an irregular declining trend of income dispersion over the entire period in contrast with other two samples depicting a consistent decline in standard deviation of per capita income. According to Hofer and Worgotter (1997) another European country exhibiting weak σ -convergence, though at a smaller rate, is Austria. Furthermore, Sala-i-Martin (1996a & 1996b) has furnished numerous substantiations for within country σ -convergence in the country analyses of Germany, U.K., France, Italy, Japan, Canada and Spain.⁵² Alongside regional evidence of convergence within each of the countries analyzed, the study has validated σ convergence for the OECD countries as well.⁵³ Conversely, the large sample containing 110 countries of the world has exemplified an overall increasing pattern in income dispersion.

Notwithstanding the presence of regional σ -convergence within the individual European countries, the cross-sectional dispersion of income for all the European regions together has shown a persistent pattern for the decade of 1980s. Sectoral analysis of labor productivity dispersion revealed σ divergence in the agriculture sector while, the industrial and services sectors have an approximate constant values of dispersion [Paci (1995)].⁵⁴ Continuing with the regional analysis of σ -

⁵² Contrary to the positive evidence of σ -convergence for the U.K., Chatterji and Dewhurst (1996) have affirmed a persistent increase in the coefficient of variation of per capita income calculated for English and Welsh counties and Scottish regions for the period 1977 to 1991. However, Germany's results of σ -convergence were also endorsed by Funke and Strulik (1999) in their study of 11 West Germany Lander. Furthermore, De la Fuente (2002) has validated σ -convergence among Spanish regions utilizing the variable of output per worker employed for the interval 1955-91.

⁵³ Later, convergence among 22 OECD countries over the time duration 1950-98 was affirmed by Nahar and Inder (2002) as well. Moreover, Romero-Avila (2009) has corroborated that the standard deviation of relative per capita GDP for OECD countries has decreased from 40% in 1870 to that of 15% in 2003.

⁵⁴ Taking into consideration the interwar periods and per capita income convergence for Western Europe, North America and Oceania (WENAO) countries, Milanovic (2003) has affirmed higher cross-country divergence during the World Wars but little σ convergence in the interwar periods. Moreover, the latter period is also characterized by high income convergence of the Atlantic economies.

convergence, Ferreira (2000) has corroborated an improvement in Brazil's interstate income distribution through both, a decreasing coefficient of variation and a 50% reduction in Theil's index over the full sample period. The parallel conclusions of reduced income inequality in Brazil utilizing both measures of income dispersion were also confirmed by Azzoni (2001). Conversely, Indian states have shown strong σ -divergence over a 25 year's period to 1994 [Nagaraj et al. (2000)]. In a study on 390 counties of the Great Plains, Austin and Schmidt (1998) have affirmed constant values of the per capita income dispersion for the initial and terminal sample years. However, σ divergence was observed for the sub-periods of 1970s and early 1980s.

Contrary to numerous within country evidence on σ -convergence, Miller and Upadhyay (2002) and Barro (1998) have validated an increase in the dispersion of GDP per worker and GDP per capita for samples of 83 and 114 countries respectively. However, Miller and Upadhyay (2002) have also reported a slight decline in the TFP dispersion during the same period. Analyses for various sub-samples have confirmed that income spread has increased within low and middle income groups, but the opposite is indicated by the high income countries. Furthermore, TFP based σ -convergence is verified only for the low and high income countries [Miller and Upadhyay (2002)]. In the convergence study by Dobson and Ramlogan (2002), Latin American countries also have shown no σ -convergence, though, a number of smaller episodes of convergence can be observed. Regarding the σ -convergence of the world countries, Grier and Grier (2007) have reached different conclusions. They have shown significant σ -convergence in physical capital, human capital, trade openness and institutional quality variables alongside significant σ divergence in per capita income; interpreting it a contradiction of NGM.

However, according to Jones (2002) and Dawson and Sen (2007), the dispersion of real per capita GDP has an overall declining trend across the states of ECOWAS and 29 world economies respectively. Though, a few sub-periods of divergence are indicated for both samples. In contrast, Lim and McAleer (2004) have endorsed the cross country σ divergence for ASEAN countries over the period 1965-92. Similarly, Solanko (2008) has reported increasing income dispersion among the Russian regions. In contrast to the usual measures of dispersion, Petrakos and Artelaris (2009) have calculated weighted coefficients of variation to analyze σ -

convergence among European regions. There is evidence of σ -convergence only within the regions of Austria, Italy and Portugal.

Initiated by Barro and Sala-i-Martin (1990), the notion of inter-relationship between β and σ convergence was later discussed in many studies. Considering the postulation that β -convergence is a necessary but not sufficient condition for σ -convergence, Lichtenberg (1994) has concluded that the former is only valid if initial and current values of income are generated by distinct autoregressive processes. Taking into account the ratio of the variances calculated for the first and last period of time-series, the author has established an F-distribution based test statistic for the σ -convergence hypothesis. Its application on the data of 22 OECD countries indicated no significant evidence of σ -convergence for the sample. Attributing the insignificance to estimation bias, Carree and Klomp (1995) have criticized the Lichtenberg's test statistic for overlooking the dependence between the two variances. Alternatively, authors have formulated likelihood-ratio test and adjusted ratio of variances test statistics. These tests have validated σ -convergence among the OECD sample not only for the period 1960-85 but also for a longer period of 1950-94. Continuing with the topic, and focusing on causality in its alternative manner, Furceri (2005) has also concluded that β -convergence always exists in the presence of σ -convergence but not vice versa. Similarly, Wodon and Yitzhaki (2006) maintained that in a uni-variate setting, σ convergence must imply β -convergence but is not valid otherwise.

Convergence analysis sourced from cross-country variation of income summarized in Table 3.7 was criticized in being unable to illustrate the dynamics of a distribution. Quah (1993a and 1993b) initiated a critical debate challenging the methodology of such cross-sectional analysis thus arguing the conclusions were inconsistent and unreliable. The author has suggested the study of entire income distribution and its temporal evolution to encapsulate better and effective convergence empirics. These will be discussed in the following section.

Table 3.7. Studies on σ -convergence			
Author/Year	Number & Nature of Cross-sectional units	Data Period	Key Conclusions
<i>Income dispersion calculated using cross-sectional data</i>			
Streissler (1979)	93 countries	1938-74	Overall decreasing trend till 1972
Baumol (1986)	16 industrialized countries	1870-1979	σ -convergence
Abramovitz (1986)			
Dowrick and Nguyen (1989)	24 OECD countries	1950-85	Decreasing trend in dispersion till 1973 but decelerated during the later period
Barro and Sala-i-Martin (1990)	48 US states	1840-1988	σ -convergence
	98 countries	1960-85	No σ -convergence
	20 original member countries of OECD	1950-85	Decreasing trend in dispersion till 1973 but decelerated during the later period
Holtz-Eakin (1993)	48 US states	1973-86	σ -convergence
Paci (1997)	109 units of 12 European countries	1981-90	No σ -convergence
Cashin (1995)	7 colonies of Australasia	1861-1991	σ -convergence
Sala-i-Martin (1996a; 1996b)	47 prefectures of Japan	1955-87	
	10 provinces of Canada	1961-91	
	17 regions of Spain	1955-87	
	11 regions of Germany	1950-90	
	11 regions of U.K.		
	21 regions of France		
	20 regions of Italy		
Chatterji and Dewhurst (1996)	English and Welsh counties and Scottish regions	1977- 91	σ divergence
Persson (1997)	24 counties of Sweden	1911-93	σ -convergence
Kangasharju (1998)	88 small-scale sub regions of Finland	1934-93	
Hofer and Worgotter (1997)	84 districts of Austria	1961-89	σ -convergence of weak degree
Austin and Schmidst (1998)	390 counties of Great Plains	1969-94	No σ -convergence
Barro (1998)	114 countries	1960-90	σ divergence
Funke and Strulik (1999)	11 regions of West Germany	1970-94	σ -convergence
Ferreira (2000)	9 states of Brazil	1970-95	
Nagaraj et al. (2000)	17 states of India	1970-94	σ divergence
Azzoni (2001)	20 regions of Brazil	1939-95	σ -convergence
De la Fuente (2002)	15 regions of Spain	1955-91	
Nahar and Inder (2002)	22 OECD countries	1950-98	
Jones (2002)	15 countries in ECOWAS	1960-90	

Michelis et al. (2004)	51 regions of Greece	1980-89	
Dobson and Ramlogan (2002)	19 Latin American	1970-98	No σ convergence
Miller and Upadhyay (2002)	83 countries	1960-89	σ divergence
Lim and McAleer (2004)	5 founding member countries of ASEAN	1965-92	σ divergence
Dawson and Sen (2007)	29 countries	1900-2001	σ -convergence
Romero-Avila (2009)	19 OECD countries	1870-2003	
Solanko (2008)	76 Russian regions	1992-2005	σ divergence
Petrakos and Artelaris (2009)	Regions within 10 European countries	1990-2000	σ -convergence for Austria, Portugal and Italy
Grier and Grier (2007)	90 world countries	1961-99	σ -convergence for physical capital, human capital, institutional quality and trade openness but not for income

3.5.2. Distributional and Time-series Approaches of σ Convergence

At the outset, Quah (1993a and 1993b) has considered the inherent assumption maintaining the existence of a steady state path for each country and confirmed its opposite by fitting a linear time trend to per capita income for a sample of 118 countries. This application of a linear trend on the standard deviation of income has not only portrayed increasing variation overtime, but an inability to move towards conditional convergence as well.⁵⁵

Continuing with the issue, the author has termed the evidence of β -convergence in a simple regression as an example of Galton's fallacy and argued that a negative estimated coefficient is in fact substantiating divergence.⁵⁶ According to him, the dynamic component disappears in time averaged growth rates and consequently renders it improper for deriving long run growth implications. Furthermore, an alternative test of convergence, involving the Markov chain transition matrix, has typified a world distinctly divided between rich and poor with no likelihood of catching up. While evaluating the traditional approaches for the

⁵⁵In a prior work on the topic with 109 countries covering the time dimension 1960-1985 and utilizing unrestricted transition probabilities for annual growth rates, the author has confirmed significant cross-section mobility both in the short and long run which are consistent with growth convergence among countries [see Quah (1992)].

⁵⁶ Earlier, Friedman (1992) has also termed cross-sectional analysis of convergence a *regression fallacy*.

estimation of convergence, another focus of Quah's (1996a) critique was the uniform and consistent result of about 2% rate of convergence despite the diversity in the spatial and temporal dimensions of data considered in previous analyses.⁵⁷ Taking into consideration the β -convergence regressions identical to a unit-root regression and drawing upon the results from the Monte Carlo distribution, the author explained this uniformity as an implication of unit root time series rather than being a dynamic economic process of catch-up.

Quah (1996a and 1996b) has tackled the issue, independent of the economic growth framework through both modeling dynamics of the entire cross-section distributions in first and higher orders and the long run kernel density for a sample of 105 countries. Resultantly, the author established the phenomenon of cross country polarization with *twin peaks*. The latter entails rich becoming richer and poor being poorer with the middle group tending to disappear. The author affirmed that the process of polarization has resulted in the formation of various clusters of countries based upon their initial characteristics. Convergence exists within these clusters of countries but there are indications of divergence in the full sample.⁵⁸ Similar notions were also the outcome of extended analyses by Quah (1996c & 1997). These entailed the estimation of stochastic kernels for the unconditioned and conditioned intra-distribution dynamics along with the formulation of a growth equation with both physical and human capital. The growth model is characterized with imperfect capital mobility across nations, while dynamics on continuous space are the significant feature of the density models.

Additionally, a 5-state Markov transition matrix of the state per capita income for USA has validated the convergence among the sample [Quah (1996a)]. Later in time, corresponding evidence in favor of convergence was endorsed by Johnson (2000) in a more comprehensive nonparametric analysis of the issue for the USA over the period 1948-93. An estimated ergodic density plot in a continuous income space characterized a uni-modal distribution having a single peak, thus negating the possibility of polarization as was depicted in the cross country data. Similarly, a non-

⁵⁷ Specifically, the spatial differences are ascribed to varied structures and distinct characteristics of cross sections.

⁵⁸ According to the estimation of λ , on average more than hundred years are required for a poor country, belonging to bottom 5%, to catch up to the rich cohort of the distribution.

parametric approach employing bootstrap multimodality and density functions was utilized by Bianchi (1997) to examine the convergence hypothesis. The density distribution of GDP for 119 countries, its log and relative transformation, were each examined for the years 1970, 1980 and 1989. Results have empirically endorsed the phenomena of polarization, bi-modality and convergence clubs in per capita income distribution along with the prevalence of very low mobility of countries within the groups. Moreover, the density estimates have also illustrated the co-existence of a large sized poor group of countries with that of a small sized rich cluster, thus nullifying the possibility of convergence in the world. Studying the ergodic distribution of sources of income growth, Barseghyan and DiCecio (2011) have indicated a long-run uni-model distribution for TFP, but not for human capital.

Alternative to Quah's methodology of a transition matrix, later studies have incorporated unit-root techniques for the analysis of σ convergence. One particular study in this context is by Evans (1996), which is based on the time-series properties of cross-country income variances. According to this particular notion, stationarity of cross-country income variances around a constant positive mean is indicative of σ -convergence. None of the four groups of countries considered in the analysis have confirmed σ divergence while the industrial countries have shown strong σ -convergence.⁵⁹

Keeping in perspective the failure of σ -convergence analysis in explaining its determinants, Rassekh et al. (2001) have developed a new approach to examine the underlying causes of income convergence. This method was applied to the data of OECD countries. The former entails the calculation of cross-country income dispersion for the adjusted income which is generated after eliminating the combined effect of all plausible growth regressors. The mixed autoregressive moving average model was used for the significance statistics of the series on the standard deviation. The results have affirmed a modest level of σ -convergence in the sample, and that too only for the period 1950-77.

Tables 3.7, presented earlier, and Table 3.8, below, have illustrated a mixed picture on the evidence for σ -convergence. Both, the regions within a country and

⁵⁹ Data for 13 Industrial countries were taken over the time period 1870-1989, while 51 countries and sample of 22 OECD countries plus Cyprus spans over 1950-1992.

small cross-country samples have corroborated a reduction in their income dispersion. However, large and heterogeneous samples of countries have either shown no σ -convergence or σ divergence. In the application of time-series techniques, small samples have often confirmed no σ -convergence, rather the opposite. However, the analysis is as yet inconclusive because of a small number of studies on the topic involving the time-series methodology.

Table 3.8. σ -convergence: Time-series Methodology

Author/Year	Number & Nature of Cross-sectional units	Data Period	Methodology	Key Conclusions
Quah (1996a and 1996b)	105 countries	1961-1988	Long run kernel density	Twin peaks and polarization in income distribution
Quah 1996c & 1997			Stochastic kernels	
Quah 1996a	48 states of USA	1948-89	5-state Markov transition matrix	σ -convergence
Johnson (2000)		1948-93	Ergodic density plot	σ -convergence
Barseghyan and DiCecio (2011)	98 countries	1960-2007	Ergodic density plot	Convergence in productivity and multimodal distribution for human capital
Evans (1996)	13 Industrial countries	1870-1989	Unit root test of cross country income variance	Strong σ -convergence
	22 OECD countries	1950-92		No σ -convergence
	51 countries			No σ -convergence
Rassekh et al. (2001)	24 OECD countries	1951-90	mixed autoregressive moving average model	No σ -convergence

3.6. CONCLUSIONS

The subject matter of income convergence has been debated in the theoretical literature for more than 50 years now, whereas the empirical literature has spanned over a quarter of a century. Beginning with the simple concepts of β and σ convergence, conditional, club and time-series forms of the concept has been incorporated in the convergence empirics. The advancement of various diverse and sophisticated econometric methodologies and their respective application have

played a pivotal role in the development of these wide ranging concepts of convergence. This would not have been possible without the formulation and availability of multiple data sets of countries spanning over a long period of time.

The empirical study of β -convergence originated with the analysis of absolute or unconditional convergence entailing the estimation of a simple regression of per capita growth on its initial value using cross-sectional data. According to Table 3.2, absolute convergence is verified only for the industrialized countries while the broad and heterogeneous sample of world countries have illustrated absolute divergence. Despite all the existing empirical evidence, the debate on the unconditional income convergence remains inconclusive; mainly because of a real dearth of studies on the topic on several dimensions.

Firstly, some of these studies focused on the variable of GDP per capita while few involved GDP per worker but none of these have done the comparative analysis of both to examine the possibility of different convergence patterns. Similarly, the topic warrants a comparative study of various groups of countries on the basis of their geographic and income classifications utilizing both GDP per capita and the GDP per worker. One of the shortcomings of the existing literature on absolute convergence is that there is no single study on the topic involving inter-continent comparisons of income convergence, while only few have deliberated on the convergence within low, medium and high income countries.

The absence of absolute convergence for a large group of countries guided us towards the introduction of the phenomenon of conditional β -convergence involving growth equations with multiple regressors mainly derived from the NGM. The underlying rationale behind the conditional convergence is to control for differences in the structural parameters of the economies and hence maintain different steady states for the sample countries. Since being more viable, conditional convergence replaced the notion of absolute convergence which was then mainly confined to within country analyses. Some of the initial researches on conditional convergence pertain to cross-sectional data analysis. However, cross-sectional data based inference of growth was thought to be inconsistent because of omitted variable bias; therefore, a panel data methodology was utilized as the better alternative. Subsequently, additional explanatory variables, the IV method and the GMM

technique were significant developments in the panel data analysis of the cross-country conditional convergence. The last column in Table 3.3 illustrates the conclusions on conditional convergence from around the world. Almost all of the studies have confirmed conditional convergence across different groups of countries; though the rate varies from below 2% to as high as 10% depending on the type of the data and the specific estimation technique utilized for the analysis.

Notwithstanding numerous studies on cross-country conditional convergence involving various groups; few of the studies have analyzed conditional convergence for the African and the Latin American continents, but the continents of Asia and Europe are yet to be investigated. Besides, maintaining the superiority of the panel data framework in the empirics of the conditional convergence, the question of a better estimation technique for the panel data analysis is not completely answered as there is only a single study on system GMM estimators compared to a few on difference GMM estimators and the IV technique. Moreover, several studies are conducted on the OECD countries, but there is a lack of a comparative study focusing on convergence analysis of the developing and the developed countries.

As far as intra-country conditional convergence is concerned, the analysis is mostly confined to the industrialized countries, with very few studies on the regional convergence of developing countries. Almost all the studies have utilized either the OLS method with cross-sectional data, or the panel data methodology to examine absolute or conditional convergence or both. A higher rate of conditional than absolute intra-country convergence tended to be found. Based on the endogenous growth theory, the notion of convergence entailing a multiplicity of steady states was another significant development in the convergence empirics. A variety of techniques are used to endorse the existence of multiple equilibriums for the world economies as reported in Table 3.5. A noteworthy outcome of the analysis of convergence with multiple steady states was the concept of club convergence encompassing convergence within distinct groups of countries. Club convergence was estimated utilizing both panel and time-series data, by analyzing as many as 119 countries of the world though only until the year 1990. Thus, an updated and comprehensive analysis of club convergence is required based on both an endogenous classification

of countries into distinct groups and perhaps utilizing advanced panel data techniques.

Parallel in time to the application of panel data techniques, time series data analysis was also introduced in the convergence empirics. In the course of time, stochastic, β , deterministic, absolute and conditional stochastic convergences were analyzed utilizing the Kalman filter and a range of pair-wise unit root, pair co-integration and panel unit root and stationarity tests. The distinguishing aspects of time-series convergence empirics are different interrelated notions, a substantial majority of studies, relatively up to date techniques and relatively recent endpoints to the time-periods. However, the majority of the studies, specifically those entailing bi-variate unit root tests with endogenous structural breaks and panel unit root/stationarity tests, have analyzed either the sample of OECD countries or of the US states. Therefore, analysis on different concepts of time-series convergence is warranted for various clusters of world countries.

Though β -convergence has numerous methodological variations, yet at times for the illustration of income convergence, its evidence is rendered as insufficient against the more feasible alternative of σ -convergence, which necessitates a declining trend of per capita income dispersion across economies. β -convergence is considered only a necessary but not sufficient condition for the σ -convergence. Table 3.7 summarized the cross-sectional data evidence on the subject which is mixed, depicting σ divergence in broad group of countries, while σ -convergence is confirmed for the industrialized countries and also for regions within a country. Nevertheless, very few studies have utilized inferential statistics for the analysis of σ -convergence. Reviews of earlier studies on the cross-sectional data approach of σ -convergence indicate the need for an additional analysis with a better methodology and data. Specifically, the application of inferential statistics in σ -convergence analysis is pertinent.

Initiated as a cross-sectional concept, σ -convergence was also estimated utilizing time-series techniques. In the σ -convergence analysis, Markov transition matrices and Kernel density functions are also used to study the dynamics of the entire income distribution. However, compared to the cross-sectional data based evidence on σ -convergence, the time-series analysis of the topic is at an early stage

and thus limited. In addition to the cross-sectional and the time-series methodologies, analysis based on distribution dynamics approach has added an interesting comparative aspect to the investigations of income convergence. Besides separate analyses for each of the concepts of convergence, an appropriate inter-relationship among its various types is required to be developed for some useful conclusions regarding the convergence/divergence of economies. Specific in this context is the relationship between β and σ convergences and their time-series and cross-sectional/panel analyses.

Finally, it is worth mentioning here that despite its wide ranging nature, both in terms of concepts and their empirical application to real world data sets, convergence empirics lack evidence for the Asian continent as a whole. Though, all other continents are part of studies for examining at least one or more notions of convergence.

Keeping in perspectives the shortcomings of the existing literature, this thesis intends to estimate both β and σ convergence in its absolute and conditional forms for the world sample utilizing the latest techniques and updated data sets. Comparative analysis of convergence based on different continents and income groups will be furnished. This research will also make an effort to synthesize different approaches and methodologies of convergence.

Chapter 4.

ABSOLUTE β and σ CONVERGENCE: EMPIRICAL ANALYSIS

4.1. INTRODUCTION

Historically, economic growth, specifically per capita income growth, is a vital ingredient for the economic development of a country, and has always been a crucial policy concern. In this context, a substantial volume of theoretical and empirical studies suggesting the plausible determinants of economic growth have been a valuable source of reference for policy makers. Despite a degree of consensus regarding some effective determinants of per capita income growth, the topic still encompasses both the time-specific and the cross-sectional approaches and hence always necessitates state-of-the-art analysis. The recent recession of 2008 and the resultant negative economic growth rates for some developing and developed countries of the world signifies another case for revisiting the topic of economic growth. Furthermore, comparative analysis of an economy's per capita income with that of its counterparts is as imperative as is the causal study of the variable for a single country or region. The former entails the concept of cross-country income convergence which because of its parallel significance has always supplemented the topic of long run economic growth. The issue of cross-country income disparity is fairly old in development economics and has been responded to in multiple manners, illuminating useful conclusions, but is continually being subject to further investigations.

This chapter presents a comprehensive analysis on absolute β and σ convergence by estimating absolute β -convergence and σ -convergence for the world sample and for its various geographic and income clusters. The primary focus is to reconsider the inter-relationship between the two notions of convergence. In this regard, unconditional β -convergence will be analyzed in part 4.2 followed by analysis of σ -convergence in 4.3. The discussion of results on both types of

convergence will be presented in the fourth part which is followed by the conclusions in part 4.5. Despite prior evidence of absolute β -divergence for the world sample, the results of this study indicate significant absolute β -convergence in the world excluding the SSA. More importantly, perhaps, the analyses confirm the existence of σ -convergence in the absence of β -convergence. Thus the estimated results contradict the commonly considered relationship between β and σ convergence. Furthermore, it is argued that β -convergence is *only* related to a specific measure of σ -convergence, but not more generally.

4.2. ANALYSIS OF ABSOLUTE β -CONVERGENCE

The hypothesis of income convergence entailing the catching-up tendency of the poor countries towards the rich countries is fairly old in macroeconomics. However, the cross-country analysis of per capita GDP pertaining to this hypothesis ranges over only a quarter of a century characterizing multiple modifications in its original formulation. This part will present the analysis of an old but pertinent topic with the latest available cross-country data spanning a period of about sixty years. Absolute β -convergence will be analyzed for different regions of the world, utilizing both cross-sectional and panel data. The first section explains the methodology involving the derivation of the absolute β -convergence regression equation from the NGM (originally derived by Barro and Sala-i-Martin (1990)). The second section illustrates different data sets and their sources utilized in this analysis. The estimation technique and the results on the absolute β -convergence will be presented in the third and the fourth sections respectively. Finally, the last section explains the misperception regarding the absolute convergence regressions.

4.2.1. Methodology: Derivation of the Regression Equation

An in-depth understanding of the concepts of absolute and conditional convergence entails a concise recapitulation of the derivation of the original convergence equation from the NGM. This was primarily contributed by Barro and Sala-i-Martin (1990) in the form given below. Barro and Sala-i-Martin (1990) have considered the conventional *Solovian* production function with labor augmenting technological

progress. This particular neoclassical production function typifies technological progress as labor augmenting because the latter is a fundamental pre-requisite for the existence of the steady state in the model. The specific form for the production function is:

$$Y(t) = K(t)[A(t)L(t)]$$

Assuming a constant returns to scale production function, positive and diminishing marginal products are exemplified each for labor and capital. Besides these characteristics, the *Inada conditions* are a noteworthy feature of the model describing that marginal products of both labor and capital are high at their respective low values and vice versa.

Taking into consideration the inputs of the function individually; the change in physical capital stock is written as:

$$\dot{K}(t) = sY(t) - \delta K(t) \quad (4.1)$$

Where \dot{K} illustrates the change in the capital stock with respect to time, s is the saving rate and δ is the rate of depreciation of the stock. The growth rates for population and technological progress are assumed to be constant and exogenously determined with their values equaled to n and g respectively. The notational illustration is:

$$\frac{\dot{L}}{L} = n, \quad (4.2)$$

$$\frac{\dot{A}}{A} = g$$

The differential equation solutions of the above generate the following values for labor and technological progress:

$$L(t) = L(0)e^{nt} \quad (4.3)$$

$$A(t) = A(0)e^{gt} \quad (4.4)$$

Owing to the postulation of constant returns to scale, the intensive form of the production function is:

$$y(t) = f(k(t)) \quad (4.5)$$

Where y and k are the output and physical capital stock per unit of effective labor respectively. Solution of $\dot{k}(t)$ yields:

$$\dot{k}(t) = sf(k(t)) - (n + g + \delta)k(t) \quad (4.6)$$

The growth rate of capital stock per unit of effective labor is equal to:

$$\frac{\dot{k}(t)}{k(t)} = \frac{sf(k(t))}{k(t)} - (n + g + \delta) \quad (4.7)$$

According to the NGM, the growth rate of capital stock at the steady state equilibrium is equal to zero. Therefore:

$$sf(k^*) = (n + g + \delta)k^* \quad (4.8)$$

In the above equation, k^* is the steady state value of capital stock per unit of effective labor.

Since $y = f(k)$, the change in output with respect to time is equal to:

$$\dot{y}(t) = f'(k) \cdot \dot{k}(t) \quad (4.9)$$

Consequently the growth rate of output is:

$$\begin{aligned} \frac{\dot{y}(t)}{y(t)} &= \left(\frac{f'(k) \cdot \dot{k}(t)}{f(k)} \right), \text{ or} \\ \frac{\dot{y}(t)}{y(t)} &= \left(\frac{f'(k) \cdot k(t)}{f(k)} \right) \cdot \frac{\dot{k}(t)}{k(t)} \end{aligned} \quad (4.10)$$

$\left(\frac{f'(k) \cdot k(t)}{f(k)} \right)$ is the output elasticity of physical capital.

Further in-depth study on the dynamics of the NGM requires the repositioning from general to the specific. In this context, Cobb-Douglas production function is the typical applied specific form of the NGM in the literature. In its usual formulation, the Cobb-Douglas production function for NGM is:

$$Y(t) = A(t)(K(t))^\alpha (L(t))^{1-\alpha} \quad (4.11)$$

Owing to the assumption of constant returns to scale, its intensive form can be written as:⁶⁰

$$y(t) = (k(t))^\alpha \quad (4.12)$$

Based on equation (4.7), the growth rate of physical capital stock is:

$$\frac{\dot{k}(t)}{k(t)} = s(k(t))^{-(1-\alpha)} - (n + g + \delta) \quad (4.13)$$

The steady state value of capital stock per unit of effective labor is obtained by equating 4.13 to zero and is equal to:

$$k^* = \left[\frac{s}{(n + g + \delta)} \right]^{1/(1-\alpha)} \quad (4.14)$$

The Solow-Swan growth model deliberates on the behavior of variables in three distinct epochs; at the start of the period, at any time period t during transition and at the steady state in the long-run. The concept of convergence entails the transitional dynamics of a variable and therefore the movement of a variable towards its steady state value. In this model, physical capital per unit of effective labor is the pivotal variable and the derivation of its convergence dynamics necessitates the log linearization of equation (4.13) around $k = k^*$:

$$\frac{\dot{k}(t)}{k(t)} = s e^{-(1-\alpha) \ln k^*} - (n + g + \delta) \quad (4.15)$$

Application of the first order Taylor's approximation on equation (4.15) generates:

⁶⁰ Based on *Schumpeterian type endogenous growth framework*, Howitt (2000) has derived similar form of steady state equation as derived by Mankiw et al. (1992).

$$\frac{d \ln k(t)}{dt} = -(1-\alpha)sk^{*(1-\alpha)}[\ln(k) - \ln(k^*)] \quad (4.16)$$

The above equation has utilized the mathematical relationship that the time derivative of the natural logarithmic function is equal to its growth rate. Moreover, it can be inferred from equation (4.13) that in and around steady state $sk^{*(1-\alpha)}$ is equal to $(n + g + \delta)$. This substitution results in:

$$\frac{d \ln k(t)}{dt} = -(1-\alpha)(n + g + \delta)[\ln(k) - \ln(k^*)] \quad (4.17)$$

By symbolizing $\beta = (1-\alpha)(n + g + \delta)$

$$\frac{d(\ln k(t))}{dt} = -\beta[\ln(k(t)) - \ln(k^*)] \quad (4.18)$$

$$\text{Or } \frac{\dot{k}(t)}{k(t)} = -\beta \left[\ln \left(\frac{k(t)}{k^*} \right) \right] \quad (4.19)$$

In the transition period, physical capital at any time t approaches its steady state value at the constant rate of β . Given the steady state value of the variable, the negative sign is indicative of an inverse relationship between the level of physical capital and its growth rate. In other words, regions with a lower initial value of capital are predicted to have higher growth of the variable, while capital rich regions are characterized by lower future growth rate of physical capital stock.

A more pertinent aspect in the derivation of transitional dynamics is to develop the output convergence equation of the economy. Equation (4.10) for the Cobb-Douglas production function takes the form:

$$\frac{\dot{y}(t)}{y(t)} = \alpha \frac{\dot{k}(t)}{k(t)} \quad (4.20)$$

Moreover, at the steady state:

$$y^* = (k^*)^\alpha \quad (4.21)$$

Equations (4.14) and (4.21) together generate the following value for steady state output:

$$y^* = \left[\frac{s}{(n + g + \delta)} \right]^{\alpha/(1-\alpha)} \quad (4.22)$$

The combination of equations (4.12) and (4.21) result in the following two alternative forms:

$$\begin{aligned} \frac{y(t)}{y^*} &= \left(\frac{k(t)}{k^*} \right)^\alpha \\ \ln \left(\frac{y(t)}{y^*} \right) &= \alpha \ln \left(\frac{k(t)}{k^*} \right) \end{aligned} \quad (4.23)$$

Substitution of equations (4.20) and (4.23) in (4.19) yields

$$\frac{\dot{y}(t)}{y(t)} = -\beta \ln \left(\frac{y(t)}{y^*} \right) \quad (4.24)$$

On the basis of inference from equation (4.19), the above equation signifies the original convergence postulation of the NGM. It illustrates that poor regions characterized with a low level of initial capital and hence low output per effective labor are exemplifying a higher output growth rate in contrast to the rich cohort. These rich regions, though having a higher initial output are exhibiting low growth because of the diminishing marginal productivity of the physical capital. Thus, the postulation entailing faster output growth for poor regions as compared to the rich ones is the conventional convergence hypothesis as is derived from the above equation.

An alternative form of equation (4.24) is:

$$\frac{d(\ln y(t))}{dt} = -\beta [\ln(y(t)) - \ln(y^*)] \quad (4.25)$$

The above equation also exemplifies the notion of β -convergence in output/income of an economy. The growth rate of output per unit of effective labor at any time t is equivalent to β times the gap between the actual and steady state levels of output. The larger is the gap between the actual and steady state value of the output, the

higher will be the growth rate of output in that economy. Diminution in the gap is taking place at the speed β which is the convergence coefficient and is identical to:

$$\beta \equiv (1 - \alpha)(n + g + \delta)$$

The above equation illustrates that the value of the convergence coefficient in an economy depends on various parameters of its growth. Along with the population growth rate, n , technological growth rate, g and the depreciation rate of physical capital, δ ; another significant determinant of the convergence coefficient is the share of physical capital in the production function, α . The diminishing returns to capital being the underlying argument for the convergence hypothesis has highlighted the crucial role of α for β . Lower values of α implies larger marginal productivity of physical capital, together with greater returns to the input and hence a larger speed of convergence and vice versa.

Equation (4.25) is a non-homogenous differential equation in $\ln(y(t))$ of the form:

$$\left[\frac{d(\ln(y(t)))}{dt} \right] + \beta \ln(y(t)) = \beta \ln(y^*)$$

Solution of the above yields:

$$\ln y(t) = (1 - e^{-\beta t}) \ln y^* + e^{-\beta t} \ln y(0) \quad (4.26)$$

Subtraction of the term $\ln y(0)$ from both sides of the equation results in:

$$\ln \left[\frac{y(t)}{y(0)} \right] = (1 - e^{-\beta t}) \ln y^* - (1 - e^{-\beta t}) \ln(y(0)) \quad (4.27)$$

As far as the estimation of equation (4.27) is concerned, the variable $y(t) = \frac{Y(t)}{A(t)L(t)}$ depicting the output per unit of effective labor posed measurement difficulties because of the technology variable, A . Thus, the output per effective labor is transformed into the output per worker as:

$$\ln \left[\frac{\hat{y}(t)}{\hat{y}(0)} \right] = gt + (1 - e^{-\beta t}) \ln A(0) + (1 - e^{-\beta t}) \ln y^* - (1 - e^{-\beta t}) \ln(\hat{y}(0)) \quad (4.28)$$

In equation (4.28), \hat{y} is output per worker. According to this equation, the growth rate of output per worker in any period t is not only caused by its initial value, but is also dependent on the steady state value of the variable. Additionally, the remaining right hand side of the equation comprising the growth rate and the initial level of technology are constant in an economy and therefore constitute the intercept term.

The study of output per worker across two distinct periods in time, the initial (0) and terminal (T), necessitates averaging equation (4.28) over the total length of period 'T':

$$\left(\frac{1}{T} \right) \ln \left(\frac{\hat{y}_T}{\hat{y}_0} \right) = g + \left[\frac{(1 - e^{-\beta T})}{T} \right] \ln A(0) + \left[\frac{(1 - e^{-\beta T})}{T} \right] \ln y^* - \left[\frac{(1 - e^{-\beta T})}{T} \right] \ln(\hat{y}_0)$$

In view of the fact that the first three terms of the above equation are constant in an economy, it is written as:

$$\left(\frac{1}{T} \right) \ln \left(\frac{\hat{y}_T}{\hat{y}_0} \right) = a - \left[\frac{(1 - e^{-\beta T})}{T} \right] \ln(\hat{y}_0) \quad (4.29)$$

It is worth noting that equation (4.29) is illustrated as equation (3.1) in the previous chapter.

Alongside the intra-country convergence, the study of convergence turns out to be more pertinent in a cross-country framework. Therefore, given the constancy *assumption* of the first three terms, equation (4.29) can equally be applicable for a cross country analysis of convergence across initial and terminal periods in its following formulation:

$$\left(\frac{1}{T} \right) \ln \left(\frac{\hat{y}_{iT}}{\hat{y}_{i0}} \right) = a - \left[\frac{(1 - e^{-\beta T})}{T} \right] \ln(\hat{y}_{i0}) + u_{i,0,T} \quad (4.30)$$

Equation (4.30) is the conventional regression equation for the examination of β -convergence hypothesis derived by Barro and Sala-i-Martin (1990). It is worth emphasizing that a positive estimated value of β coefficient in equation (4.30) is indicating β -convergence and vice versa. The inclusion of the steady state output per

worker in the constant intercept term characterizes the existence of a common steady state for all the countries; a noteworthy and crucial assumption of the convergence equation. As mentioned in the previous chapter, the particular analysis of the cross country income convergence on the basis of the assumption of common steady state is termed as *Unconditional Convergence* or *Absolute Convergence*. Absolute convergence assumes the identical level of per capita income for all the countries in their long-run steady state, irrespective of the countries' initial conditions and their structural parameters in the transition period.

After a comprehensive explanation of the methodology, the subsequent section will deliberate on the data types and sources utilized for the estimation of the derived convergence equation.

4.2.2. Data and Sources of the Data

In the discussion on the historical trends of per capita income in the section 2.3.1, the study sample consists of 137 countries over the time period 1950-2008. As mentioned earlier, the data for the real per capita GDP at PPP is measured in Geary Khamis dollars and is sourced from Maddison's database. Due to the non-availability of the longer datasets on the employed labor for a larger cross-section of countries, the variable of the GDP per worker is constructed using the series of the working age population. The statistics on the working age population are accessed from the World Bank database in which this series is available for the time-range 1960-2008. The figures for 1950 and 1955 were calculated with the information taken from the UN database which furnishes the data on the population by their age group. These two sources provide the statistics on the working age population for all the sample countries of the study with the exception of Taiwan and the Seychelles. The required data for the former is obtained from the online databank of the National Statistics, Republic of China (Taiwan). However, due to the non-availability of data for the latter, this country is excluded from the total sample which now reduces to 136 countries over the aforementioned time-span, 1950-2008.

The analysis utilizes both cross-sectional and panel data frameworks. Past studies on absolute income convergence have typically utilized cross-sectional data.

Meanwhile, panel data estimations involve the dynamic component together with the characterizations of greater variability and larger degrees of freedom; hence rendered as more pertinent in the growth empirics. Because of its dynamic component, Friedman's (1992) criticism on the methodology of β -convergence cannot be extended to the panel data estimations of β -convergence. Keeping in perspective the early panel data estimations of economic growth and income convergence e.g. Knight et al. (1993), Loayza (1994) and Islam (1995); time-series observations in this study are based on a five years interval.

Utilizing these cross-sectional and panel data sets, absolute convergence is investigated for the aggregate sample of world countries together with its four geographic country-groups namely, Asia, Europe, Africa and Latin America & the Caribbean. However, the category of western off-shoots is excluded from this analysis because of a very small sample size consisting of the four cross-sectional units only. Bearing in mind the preceding discussion on the long-run income growth in part 2.3, the second country classification incorporated in this section is based on various income groups, i.e. low, lower middle, upper middle and the high income. Analysis for each of the geographic and income categories is accomplished by both including and excluding some oil producing countries. Despite their diverse levels of the measured GDP, a number of oil rich countries are an outlier in a conventional economic growth framework because of very low value added each year. Based on this criterion; Mankiw et al. (1992) have specified a group of countries consisting of Bahrain, Gabon, Iran, Iraq, Kuwait, Oman, Saudi-Arabia and the United Arab Emirates (UAE). Adhering to the analysis by these authors, a similar sample of oil countries is considered in this study with the exception of a single addition to the list. Because, one of the oil rich countries, Qatar was not included in the entire set of cross-sections by Mankiw et al. (1992) but it is part of the sample in this study. Because petroleum accounts for more than 60% of the GDP of Qatar; the country is also added in the list of the excluded oil rich countries.⁶¹

⁶¹<http://www.capitalme.com/content.aspx?numNWSRCDID=698&vcNWSID=59200725030835157367&numNWSWEBCATID=42>

4.2.3. Estimation Technique

Unconditional β -convergence based on equation (4.30) is equally applicable with the variable of GDP per worker or the per capita income of countries [Barro et al. (1991)]. Using both of these variables, this equation is estimated for the world sample and for its different country groups applying the non-linear least squares technique. Non-linear least squares estimation gives the direct value for the speed of the convergence, β . The drawback of the alternative estimation technique, OLS, on the linear form of the equation is that the coefficient on the initial income turned out to be dependent on the time-length in the sample, T. Consequently, comparisons of the convergence coefficients estimated with different time-periods are implausible [Sala-i-Martin, (1996b)]. On the other hand, the convergence coefficient is characterized to be independent of the total time-range in the non-linear least squares estimation.

The regression analysis pertains to equation (4.30) and is based on the datasets for the world sample and its various categories. Empirical analysis for unconditional convergence is primarily carried out using the STATA-10 software and the obtained results are also confirmed through re-estimations on Eviews-7. The cross-sectional estimations are tested for heteroskedasticity utilizing the White test and in the presence of heteroskedasticity the White heteroskedasticity-consistent standard errors are reported instead of the ordinary ones. Similarly, panel data regression estimations are examined for both autocorrelation and heteroskedasticity. In the presence of either or both problems, suitable form of the panel corrected standard errors (PCSE) is replaced with the original ones. Additionally, graphical depiction by means of scatter graphs between the average growth and the initial value of the variable is an auxiliary tool utilized for the investigation of the topic.

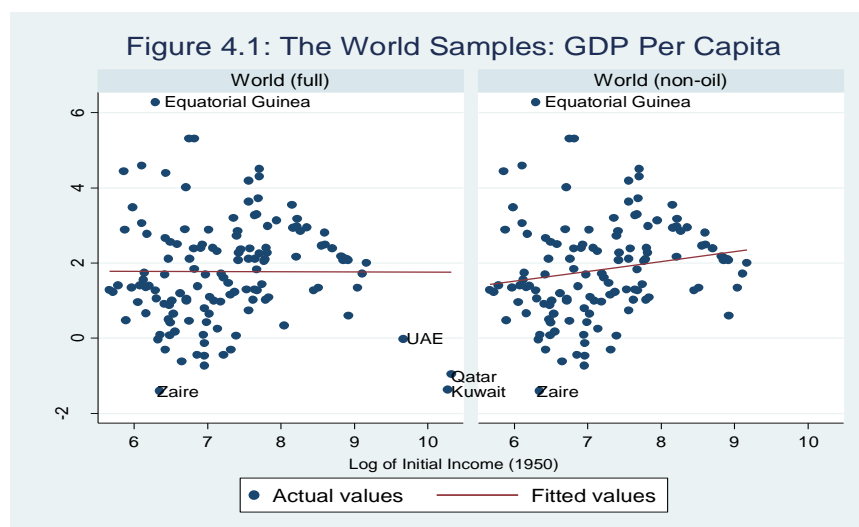
4.2.4. Results on β -convergence

Results for the world sample and its eight different categorizations with both the cross-sectional and panel data are reported in Tables 4.1 and 4.2 for the variables of real per capita GDP and real GDP per working age person respectively. Both the

graphical and the regression results on absolute income convergence are presented in the following.

Beginning with the world sample, the scatter graphs of GDP per capita for the full and non-oil samples are illustrated in Figure 4.1. The prominent outliers in the full world sample are the three oil rich countries namely Qatar, UAE and Kuwait, in the bottom right corner with their very high initial incomes and negative average income growth rates. Besides, the figure is also illustrating both the negative and zero values of the growth rates for some other countries. Located in the bottom left corner of these two scatter-grams, is the worst performing country with the minimum growth value of -1.4%. This is the Democratic Republic of Congo formerly known as Zaire. Despite rich natural resource endowments, its persistently poor economic performance is sourced from hyperinflation, several years of civil wars, poor infrastructure, corruption, disease and famine [Renton (2007)]. Resultantly, this country presently has one of the lowest per capita incomes in the world.

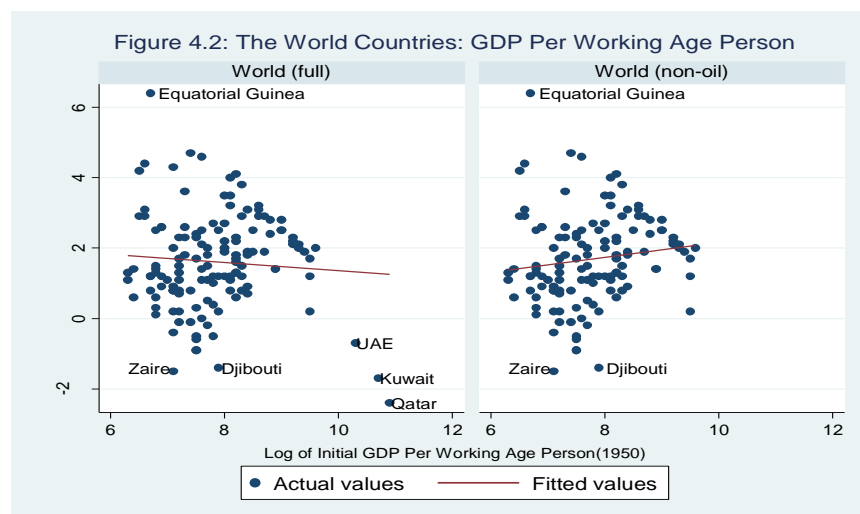
Conversely, a few of the countries have also attained the average income growth figure of above 4%. The observation on the top left corner in both these figures pertains to the highest growth value of above 6% which relates to the country of Equatorial Guinea. This is a small central African country with the population of less than a million. The growth value of 6% is the outcome of remarkable growth of the per capita income in the last two decades averaging at 17% and 15% in 1990s and 2000-08 respectively. The discovery of massive offshore petroleum resources in



the early 1990s and the resultant high petroleum exports are major factors behind this extraordinary economic performance [Weeks (2001)]. In 2010, the country is the third largest oil producer in SSA.⁶²

Taking into consideration the variable of GDP per working age person, Figure 4.2 depicts the scatter graphs for the full and the non-oil samples of the world respectively. These scatter spreads are similar to the graphs of the GDP per capita; three oil countries are the outliers on the bottom right corner together with Equatorial Guinea being the highest growing country. However, another small African country, Djibouti, is parallel in performance to that of Democratic Republic of Congo for the lowest growth figure of -1.4%. These low levels of per capita income have resulted in huge unemployment and poverty in the country. The lack of natural resources and inadequate industrial and agricultural structures along with an unfavorable climate are the main causes of the poor macroeconomic and social indicators in Djibouti [African Development Bank (2007)].

As far as the convergence among the world countries is concerned; regardless of their initial income levels, the majority of these countries have attained an average income growth between 1% and 4%. This is also exemplified by the almost horizontal shape of the fitted regression line in the first half of Figure 4.1 which neither indicates a clear positive nor negative relationship between these two variables. However, with a positive slope, the regression line for the non-oil sample



⁶² <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2173rank.html>.

depicts income divergence. Despite a fairly comparable spread, the fitted regression line for the GDP per working age person is indicating a slightly negative slope for the full sample as visible in Figure 4.2. However, with the same variable the regression line for the non-oil world countries is positively sloped which is parallel to that of the GDP per capita illustrated in Figure 4.1.

Bringing the regression estimations into the picture, the cross-sectional and panel data analyses exemplified an insignificant relationship between the average growth and the initial value of GDP per capita and GDP per working age person for the full world sample in Table 4.1 and Table 4.2 respectively. Similar findings of an insignificant β coefficient for the non-oil sample with the cross-sectional data using the GDP per working age person is reported in Table 4.2. However, the negative and significant β coefficients of the GDP per capita in Table 4.1 for both non-oil samples have substantiated the positively sloped regression lines together with divergence evidence of the convergence hypothesis. In the same way, Table 4.2 confirmed the divergence for the non-oil world sample with the negative and significant panel data coefficient for the GDP per working age person as well. But this coefficient of divergence is lower compared to that of the GDP per capita. The values of all β coefficients are very small and the rates of divergence range from 0.2% to 0.3%.

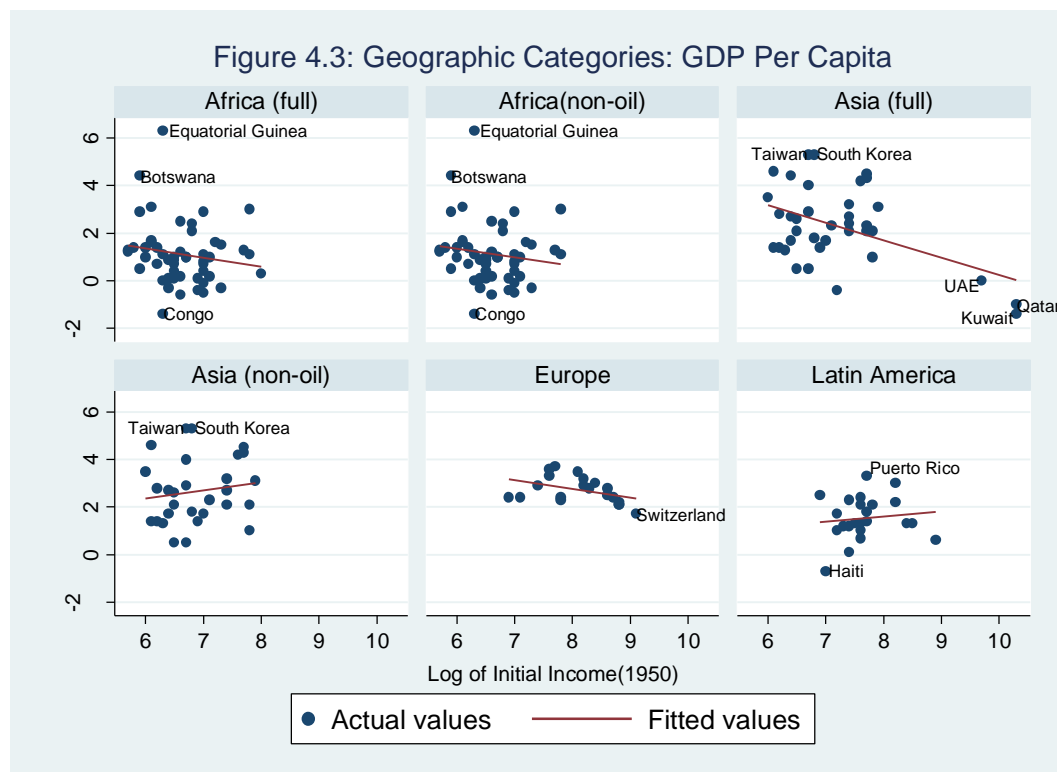
The income divergence evidence from the world sample alone is not sufficient for a firm conclusion on the absolute convergence hypothesis. Further investigations on the subject based on the geographic and income classifications of the world countries are also incorporated. Considering the geographic categorization, the first region in the alphabetical list is the continent of Asia. Across the entire range of the study period, this region has achieved the highest and most persistent average per capita income growth given in tables 2.1 and 2.2. Except for a few of the oil producing countries namely, Qatar, Kuwait, U.A.E and Iraq, all the Asian countries have attained positive income growth depicted by the scatter graphs in Figure 4.3. Two of the East Asian tigers, South Korea and Taiwan, are the top income growing countries jointly located in the upper left corner of the graph, each with an average growth value of 5.3%. Explaining the remarkable economic progress in these countries, Rodrik (1995) has rendered the higher levels of human and physical capital accumulations as the two most significant determinants of this expansion. In

Table 4.1. Unconditional Income Convergence: Global Analysis								
GDP Per Capita								
Region\Results	Cross-sectional full		Cross-sectional non-oil		Panel data full		Panel data non-oil	
	$\hat{\beta}$	R^2 [n]	$\hat{\beta}$	R^2 [n]	$\hat{\beta}$	R^2 [n]	$\hat{\beta}$	R^2 [n]
World	0.000035 (0.024)	0.0001 [136]	-0.0024* (-2.41)	0.03* [127]	-0.0013 (-1.82)	0.002 [1632]	-0.0030** (-5.39)	0.012** [1524]
Asia	0.0095* (2.30)	0.21** [37]	-0.0034 (-0.965)	0.027 [29]	0.0043* (2.45)	0.014** [444]	-0.0036* (-2.16)	0.013* [348]
Africa	0.0044 (1.02)	0.027 [51]	0.0031 (0.75)	0.014 [50]	-0.00007 (-0.03)	0.00001 [612]	-0.00014 (-0.05)	0.0001 [600]
Europe	0.0042 (1.53)	0.18 [21]	N/A		0.0096** (2.76)	0.13** [252]	N/A	
Latin America & the Caribbean	-0.0021 (-0.59)	0.014 [23]	N/A		-0.001 (-0.41)	0.001 [276]	N/A	
World excluding SSA	0.004* (2.34)	0.07** [91]	0.0006 (0.42)	0.002 [83]	0.0026** (2.67)	0.01** [1092]	0.0002 (0.22)	0.00001 [996]
High income	0.02* (2.44)	0.81** [12]	0.013 (0.39)	0.01 [9]	0.027* (2.82)	0.10** [144]	0.006* (2.17)	0.04* [108]
Upper middle income	0.054 (0.24)	0.23 [13]	N/A		0.009* (2.94)	0.06** [156]	N/A	
Lower middle income	0.076 (0.05)	0.03 [27]	-0.0003 (-0.014)	0.0001 [24]	0.0025 (0.97)	0.003 [324]	0.0003 (0.14)	0.0001 [288]
Low income	0.003 (0.8)	0.01 [84]	0.0028 (0.68)	0.007 [81]	-0.0027 (1.61)	0.003 [1008]	-0.0036* (-2.18)	0.01* [972]
<p>(.) denotes the t-statistics; [n] indicates number of total observations in the regression. * indicates significance at 5% level, ** indicates significance at 1% level. Significance of R^2 is based on the F-statistics. N/A in some of the results for the non-oil sample refers to the fact that none of the excluded oil countries are part of this specific categorization. The unconditional convergence is estimated by applying non-linear least squares technique on $\left(\frac{1}{T}\right)\ln\left(\frac{\hat{y}_{iT}}{\hat{y}_{i0}}\right) = a - \left[\left(1 - e^{-\beta T}\right)\right] \ln(\hat{y}_{i0}) + u_{i,0,T}$. Convergence requires β to be significantly positive. The initial year for the analysis is 1950, while the last period 'T' for the sample is 2008. The panel estimations involve 12 time-series data points by taking 5 yearly intervals. The cross-sectional estimations are tested for heteroskedasticity utilizing the White test and if necessary the White heteroskedasticity-consistent standard errors based t-statistics are reported. Similarly, as per the requirement of the panel regressions, the suitable form of the panel corrected standard errors (PCSE) is replaced with the original ones.</p>								

Table 4.2. Unconditional Income Convergence: Global Analysis GDP Per Working Age Person								
Region\Results	Cross-sectional full		Cross-sectional non-oil		Panel data full		Panel data non-oil	
	$\hat{\beta}$	R ² [n]	$\hat{\beta}$	R ² [n]	$\hat{\beta}$	R ² [n]	$\hat{\beta}$	R ² [n]
World	0.0012 (0.66)	0.006 [136]	-0.002 (-1.75)	0.017 [127]	0.00005 (0.07)	0.00001 [1632]	-0.002** (-3.26)	0.005** [1524]
Asia	0.013** (2.95)	0.30** [37]	-0.002 (-0.61)	0.011 [29]	0.0065** (3.21)	0.03** [444]	-0.002 (1.13)	0.003 [348]
Africa	0.008 (1.49)	0.07 [51]	0.0086 (1.46)	0.07 [50]	0.0026 (0.94)	0.002 [612]	0.0022 (0.78)	0.002 [600]
Europe	0.0036 (1.45)	0.154 [21]	N/A		0.011** (2.83)	0.16** [252]	N/A	
Latin America & the Caribbean	-0.002 (-0.65)	0.02 [23]	N/A		0.0018 (0.67)	0.002 [276]	N/A	
World excluding SSA	0.005** (2.68)	0.1** [91]	0.001 (0.94)	0.01 [83]	0.004** (3.86)	0.014 [1092]	0.001 (1.41)	0.002 [996]
High income	0.03* (2.33)	0.80** [12]	0.01 (0.41)	0.28 [9]	0.028** (3.81)	0.11** [144]	0.012* (2.45)	0.09** [108]
Upper middle income	0.032 (0.54)	0.19 [13]	N/A		0.013** (4.04)	0.10** [156]	N/A	
Lower middle income	0.07 (0.1)	0.05 [27]	0.052 (0.127)	0.03 [24]	0.0075** (2.59)	0.021** [324]	0.0048* (2.24)	0.011 [288]
Low income	0.007 (1.39)	0.034 [84]	0.006 (1.32)	0.031 [81]	0.0002 (0.11)	0.00001 [1008]	-0.0007 (-0.39)	0.0002 [972]
Notes: see Table 4.1.								

another view, alongside higher levels of investment and exports; favorable initial conditions such as a high literacy rate and the equitable income distribution are the distinct characteristics of the economic growth both in South Korea and Taiwan [Booth (1999)].

The fitted regression line for the full Asian sample in Figure 4.3 is negatively sloped indicating the considerable level of absolute income convergence among the Asian countries. Notwithstanding the greater part of the sample being on the left side of the figure, the sizeable negative slope is caused by the three oil countries on the bottom right corner. The negative relationship between the initial income and subsequent growth pertaining to the concept of absolute income convergence is typified in an unusual manner by these three countries. Since, these countries have the highest levels of initial per capita income together with the lowest and negative



values of the average income growth rates. Therefore, the negative slope of regression line for the full sample overturns into a positive shape for the non-oil Asian sample as portrayed in Figure 4.3. The latter invalidates the income convergence evidence of the full Asian continent in support of income divergence in

the non-oil sample of the region. Scatter graphs of the Asian sample involving the GDP per working age person are not presented here because of their similar patterns as with those of per capita GDP.

The regression results of the Asian sample given in Tables 4.1 and 4.2 have supported the findings of the graphical analysis between average growth and the basic income. The cross-sectional and panel data estimations confirmed the convergence among the full Asian sample with positive and significant β coefficients for both the per capita income and GDP per working age person. While, all the β coefficients based on the GDP per working age person of the non-oil sample are insignificant. In contrast, the negative and significant β coefficient for GDP per capita in the panel non-oil sample is indicative of income divergence. The respective positive and negative β coefficients with per capita income for the full and non-oil samples may endorse the strong impact of the unusual convergence pattern of the oil rich countries on the regression results for the full sample.

An additional input in this analysis is to compare the findings on the income convergence with the historical trends of the long-run income growth reported in Tables 2.1 and 2.2. The high and consistent growth figures, together with an overtime reduction in the measure of income spread for the continent, are quite the opposite of the income divergence evidence for the non-oil sample. In view of the fact that the analysis in Table 2.1 has focused on the entire region without any distinction of the full and the non-oil samples; this declined income spread pertains to the full Asian region. Moreover, for the non-oil Asian sample, the value of the ratio between the highest and the lowest income has increased from 7 in 1950 to 36 in 2008. Another possible explanation is the diversity in the economic performance of the Asian countries regardless of the relatively low levels of the per capita income for almost all the countries in 1950. A few of these nations, predominantly East Asian, have achieved more than 4% of the average income growth. Besides, there is larger cluster of the slow growing countries with an average growth value of around or less than 2%.

The plausible regional comparison for the Asian continent is with that of Africa because of similar levels of development in the majority of the Asian and the African countries till 1950. Contrary to Asia, the African continent is characterized

with the record of the lowest and most volatile income growth figures along with the relatively large population expansion as discussed in part 2.3. Scatter graphs between the growth and initial per capita income for the full and non-oil samples of Africa are illustrated in Figure 4.3. Equatorial Guinea is the highest income growing country followed by Botswana with its figure of 4.4%. The average income growth for Botswana was around 6% over the period 1960-2000 which is mainly attributed to the diamond mining after its large-scale extraction in 1966. However, the economy is also characterized with industrial development, better governance, appropriate macroeconomic policies and market oriented development policies, together with considerable levels of the foreign investment and aid [Fosu (2008); Sentsho (2003)].

In contrast to the strong growth figures of these two economies, the overall growth performance of the African countries is fairly weak [see Table 2.1 and Table 2.2]. As mentioned earlier, the Democratic Republic of Congo has the most negative and the lowest income growth equaling -1.4%. Besides, the majority of the countries in the continent have either a negative, or less than 1% growth, over a length of more than a half century as is evident from Figure 4.3. Referring to the economic under-performance, Fosu (2008) has ascribed strict government regulations, poor redistribution, inter-temporal and state breakdown as the *anti-growth syndromes* in Africa. The author further added that nearly three-quarter of the countries are permanently trapped in these syndromes which are root causes of the poor economic and social conditions of the majority of the continent.

In the graphical analysis, the fitted regression lines for the full and non-oil samples given in Figure 4.3 have similar patterns because of only a single African nation being in the list of the excluded oil rich countries. Both of the curves are marginally negatively sloped indicating no significant evidence of income convergence in the sample. Scatter graphs with the GDP per working age person are not presented for this region, due to similar convergence patterns. Corresponding to the graphical analysis, the regression results, in Table 4.1 and 4.2, both with cross-sectional and panel data of GDP per capita and GDP per working age person are indicative of no significant relationship between the average growth and the initial value. Even the oil and the non-oil samples do not add any variation into the overall results for the African region.

In contrast to the above illustrations of the inconsistent long-run income growth together with no evidence on convergence are the growth and convergence empirics for the continent of Europe. Over the study period 1950-2008, Europe has the second highest average income growth figure of 2.5% though with a fairly sizeable initial level of median per capita income as well [see Table 2.1]. The scatter graph between the average growth and the initial value of the GDP per capita is presented in Figure 4.3. There is no categorization of the full and the non-oil sample because of the absence of any excluded oil rich countries in this region. The graph is indicative of the fact that none of the European countries has a negative income growth and the majority of the sample has a growth figure of above 2%. The country on the bottom right corner of the graph is Switzerland with the highest income value in 1950 alongside the subsequent lowest average growth figure of 1.7%. Bearing the minor difference among their values, the top three income growing countries are Spain, Greece and Ireland.⁶³ Nevertheless, there is not much variation in the average growth figures of the European countries as indicated by the figure. Similarly, the descriptive measure of income spread has earlier illuminated minor differences in their per capita income levels both for the initial and the terminal years [see Table 2.1]. Alongside the smaller income spread, the negative slope of the regression line is illustrating the income convergence among the European countries. The latter is also confirmed by the positive and significant panel data β coefficients using both the GDP per capita and the GDP per working age person. The rate of absolute convergence is around 1% for these analyzed variables. However, the convergence coefficients are insignificant in the cross-sectional estimations for Europe.

The final geographic region to be discussed in the context of absolute income convergence is Latin America and the Caribbean, with an average income growth of 1.8% for the entire region. As far as the individual countries in the region are concerned, the scatter graph in Figure 4.3 furnishes a better depiction of their initial incomes and the subsequent average growth rates.⁶⁴ The tallest point of the graph represents Puerto Rico, which has attained average income growth of 3.3%. Since the

⁶³ It is worth mentioning that in the recent years, these three European countries are facing serious economic problems. According to the World Bank data source, the per capita income growth rate in 2009 for Greece, Ireland and Spain equals - 2.4%, - 7.6% and - 4.5% respectively.

⁶⁴ Like the European sample, there is no distinction between the full and the non-oil sample for this region as well.

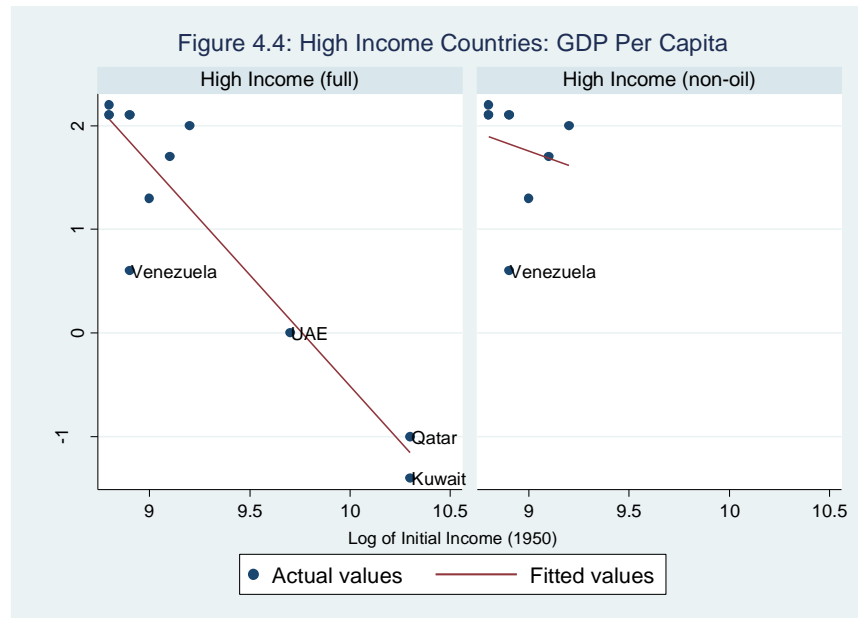
state is a US commonwealth, it owes the growth of its manufacturing sector to both the foreign investment by US corporations and the free access to US markets [Bulmer-Thomas (2003)].⁶⁵ This resulted in the export-led high economic growth for the country over the period 1950-75 [Bulmer-Thomas (2003)]. However, the rate of growth reduced during the subsequent years because of the lower TFP growth in the economy [Bosworth and Collins (2006)]. In contrast to Puerto Rico, Haiti is the worst performing country in this region characterized with the low initial income and the lowest average growth. This poorest country of Latin America & Caribbean has negative income growth equaling -0.7%. The political instability, lack of proper institutions, corruption and improper economic policies are considered to be the fundamental causes of economic decline [Loayza et al. (2004); Khan (2010)]. The regression line in this figure is slightly positively sloped indicating income divergence within the Latin American region. This evidence may endorse the earlier information regarding the size of the income spread for Latin American & Caribbean region in Table 2.1, which is five times bigger in 2008 compared to its value in 1950. However, with the insignificant β coefficients, the regression results for each of the output variable using both the cross-sectional and panel data have neither corroborated convergence nor divergence for the Latin American & Caribbean countries.

The absolute convergence analysis of the world has revealed income divergence, while its various geographic regions have mainly exemplified mixed evidence on income convergence among the countries. The continents of Europe and Asia have significant evidence for the convergence using the variables of per capita income and the GDP per working age person; while, the opposite holds for the African and Latin American continents.

Alternative to the geographic classification of countries, the endogenously devised income categorization is also used in the convergence analysis for further insights. As mentioned in part 2.3, this classification is based on the per capita income of 1950 and the four country groups are the high income, upper middle income, lower middle income and the low income. Considering the hierarchy from the top, the high income category comprises 12 countries which include the oil-rich

⁶⁵ <https://www.cia.gov/library/publications/the-world-factbook/geos/rq.html>

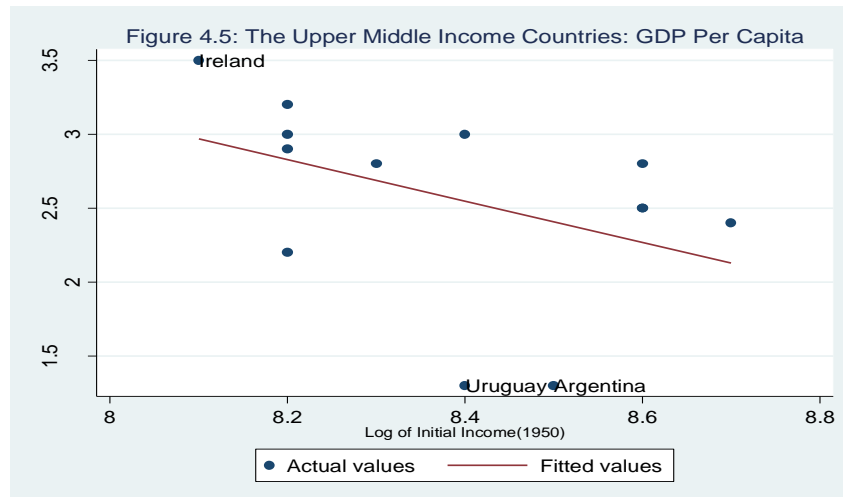
economies as well. The scatter graphs between the initial income and the average growth for the full and the non-oil samples are given in Figure 4.4. The fitted



regression line has a sizeable negative slope indicating income convergence among the high income countries. With the exclusion of the three oil-rich countries, the regression line for the non-oil sample forms a less steep negative shape. Nevertheless, all the regression estimations confirm the convergence in both of these samples for the high income category, but the results from the cross-sectional estimations of the non-oil sample are insignificant. The rate of convergence for the full sample is higher than that for the non-oil group. Similarly for the cross-sectional full and panel non-oil samples, the convergence coefficient for GDP per working age person is higher than that of GDP per capita.

The second category, namely the upper middle income group, with its 13 countries taken together, has a reasonable income growth record. In this context, the scatter graph in Figure 4.5 is a further illustration of the relationship between the initial income and the average growth. All the countries in the group have a positive income growth while, Ireland has attained the highest growth of 3.5%. The growth figure is contributed to by the remarkable macroeconomic performance of the Irish economy over the period 1995-2007 in which the average income growth equals 6.2%. Owing to its sudden economic expansion, the Irish economy is also termed as

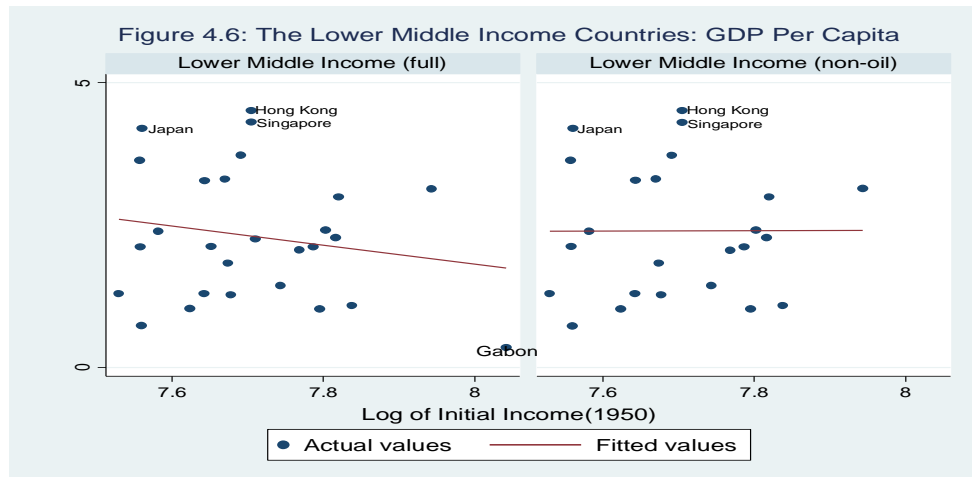
the *Celtic Tiger*. The openness of the economy, the US boom, EU subsidies and sound macroeconomic policies are considered as the significant sources for this extraordinary economic growth [Breathnach (1998)]. Although in recent years it has of course encountered severe economic problems.



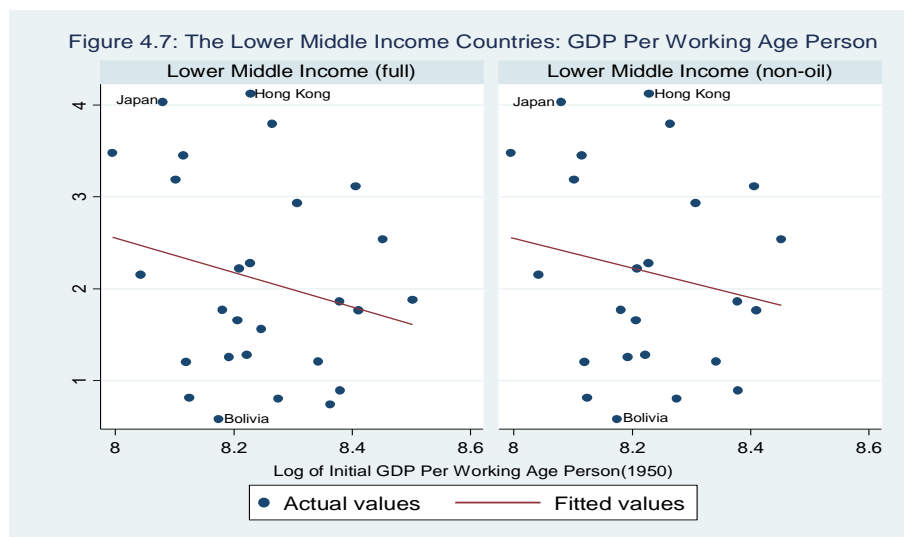
The negative slope of the regression line in Figure 4.5 indicates per capita income convergence among the upper middle income countries. This is also validated by the panel data regression results for GDP per capita and GDP per working age person. The convergence coefficient for per capita income is slightly lower than that with the other variable. The rates of absolute convergence are approximately equal to 1%. However, the cross-sectional analysis has not generated any significant results.

Compared to the high and the upper middle income groups, the lower middle income category consists of a larger number of countries including the three oil-rich economies, namely, Bahrain, Gabon and Saudi Arabia. The scatter graphs of the per capita income and growth for the full and the non-oil samples are presented in Figure 4.6. Located in the bottom right corner of the graph is Gabon, an African oil country, with the highest initial per capita income in combination with the lowest growth. The low figure is contributed by the negative average income growth of the last three decades. This is largely due to the two external shocks namely oil price instability in 1980s and France's devaluation of the CFA franc in the mid-1990s. Conversely, the growth rates for the three East Asian countries in the group, Hong Kong, Singapore

and Japan, are equal to 4.5%, 4.3% and 4.2% respectively. The scatter graphs for the full and the non-oil sample using the GDP per working age person are presented in Figure 4.7.



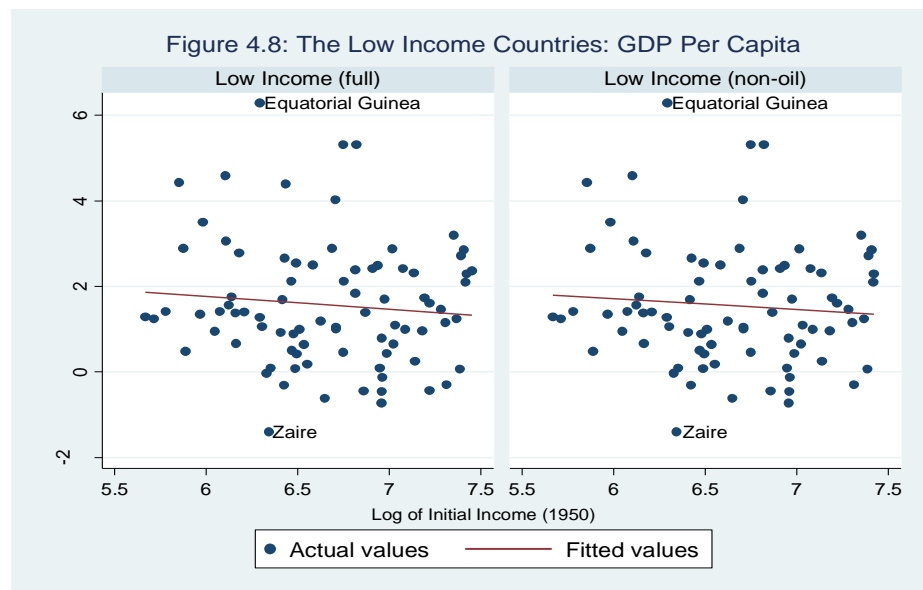
The fitted line for the full sample has a small negative slope which has changed after the exclusion of the oil-rich countries. The regression line is horizontal



in Figure 4.6 illustrating no income convergence among the non-oil lower middle income countries. However, the fitted lines for the full and non-oil samples with the GDP per working age person are negatively sloped. Likewise, the regression estimations have also confirmed convergence using the variable of GDP per working age person. Though the coefficients based on the cross-sectional analysis are

insignificant; the panel data coefficients are positive and significant with their values of 0.8% and 0.5% for the full and non-oil samples respectively. However, no significant coefficients for this income group are reported in all the estimations using per capita income.

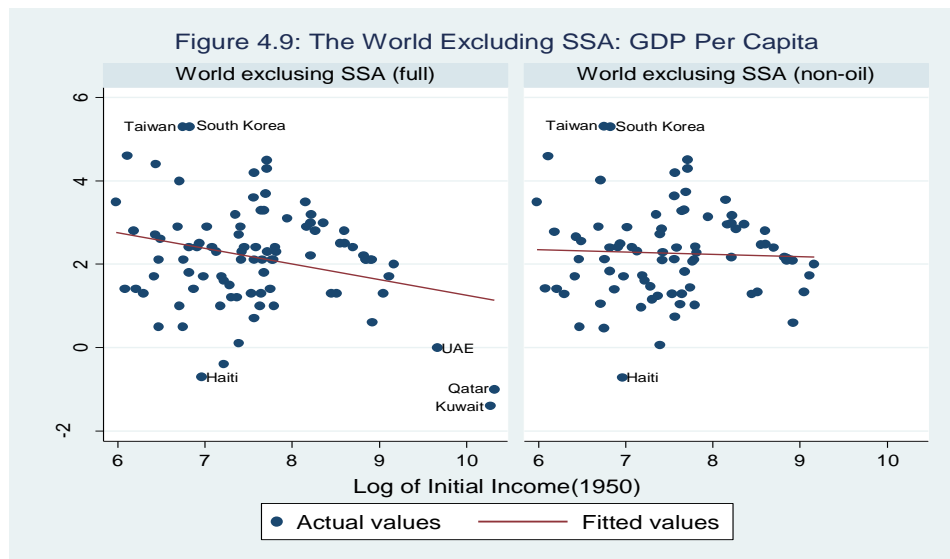
According to the income classification, the largest number of countries appeared in the low income category which is also characterized with the highest average income growth figure alongside the huge increase in the income spread given in Table 2.1. Figure 4.8 illustrates the scatter graph of the income growth and initial income for the full and non-oil samples. Equatorial Guinea has attained the highest growth figure followed by the South Korea and Taiwan. There are also a few more countries with the growth value of above 4%. On the other hand, the minimum growth value pertains to the Democratic Republic of Congo, along with a number of other countries having negative average income growth.



The scatter graph for the low income category reveals no relationship between the initial incomes and subsequent income growth rates of the countries. Resultantly, the fitted line is nearly horizontal in both of the samples for the low income category. Similar are the trends of the regression lines with GDP per working age person for the full and the non-oil samples, and for this reason are not portrayed. In the same way, all the regression estimations involving GDP per working age

person have exemplified insignificant β coefficients. However, the only significant result with the GDP per capita has confirmed income divergence among the non-oil sample of the low income countries. The rate of income divergence for the low income group is very small; since the value of the panel data coefficient equals -0.4%.

Finally, owing to the largest count of SSA countries (45) in the low income category even in 2008, another sample of the world countries with the exclusion of SSA region is also studied. The scatter graphs for the full and non-oil samples are given in Figure 4.9. Interestingly, the previous finding of no income convergence for the full world sample has turned into β -convergence among the sample which is evident from the negative slope of the fitted line in the scatter graph. However, the horizontal line for the non-oil sample illustrates no income convergence. The regression estimations have also endorsed the graphical depiction with the positive and significant β coefficients for the full sample while, the convergence results pertaining to the non-oil sample in tables 4.1 and 4.2 are all insignificant.



The above analyses have exemplified more frequent evidence in support of the absolute convergence for different income classifications than for the geographic regions. The high income and the upper middle income countries are converging within their respective classification. But, findings in support of the absolute

convergence were not widespread in the lower middle income category and was strictly lacking in the low income group.

4.3. ANALYSIS OF σ -CONVERGENCE

In the convergence literature, absolute β -convergence is often analyzed in combination with an alternative notion, namely σ -convergence which is based on the cross-sectional dispersion of income/output over any particular time-span. Owing to its significance, particularly in the context of the association with β -convergence, a comprehensive analysis of σ -convergence will be presented in this part.

4.3.1. Relationship between β and σ Convergence

The regression analysis pertaining to unconditional β -convergence was criticized by Friedman (1992). Specifically, the author has opposed the cross-sectional estimations of the convergence equation because they are based on the averages for the entire time-period. The conclusion on the income convergence based on the latter is referred as the *regression fallacy* instead of being an indication for the poor becoming the rich. As an alternative to β -convergence, Friedman has rendered the temporal study of the cross-sectional dispersion of income more plausible for the definite conclusions on the income convergence.⁶⁶ However, even prior to Friedman's recommendation, the trend in the cross-country income dispersion was analyzed in the convergence empirics together with the β -convergence. The former was termed as σ -convergence and, based on its interrelationship, was also derived from the equation of β -convergence [Barro and Sala-i-Martin (1990)].

Beginning with equation (4.30) for the absolute β -convergence discussed in the last section, Barro and Sala-i-Martin derived the interrelationship between the two concepts of convergence as follows:

⁶⁶Later, Bliss (1999) contradicted Friedman's idea of regression fallacy regarding β -convergence regressions. The author asserted that the cross-sectional estimates of β are biased only in the presence of a unit root in the data generating process. But, Cannon and Duck (2000) have rejected the latter argument and endorsed the phenomenon of the regression fallacy.

$$\left(\frac{1}{T}\right)\ln\left(\frac{\hat{y}_{iT}}{\hat{y}_{i0}}\right) = a - \left[\frac{(1 - e^{-\beta T})}{T}\right]\ln(\hat{y}_{i0}) + u_{i,0,T} \quad (4.30)$$

Instead of considering the initial and the terminal periods as above, the equation for any two discrete time points t and $t - 1$ can be re-written as:

$$\ln\left(\frac{\hat{y}_{it}}{\hat{y}_{it-1}}\right) = a - [1 - e^{-\beta}]\ln(\hat{y}_{it-1}) + u_{it} \quad (4.31)$$

In the above equation, negative signs attached with the β , the exponent term and with the coefficient $[1 - e^{-\beta}]$ together are indicative of the negative relationship between the initial income and the subsequent growth implying convergence among the countries. Combining both of the lagged terms to the right-side of the equation results in:

$$\ln(\hat{y}_{it}) = a + e^{-\beta} \ln(\hat{y}_{it-1}) + u_{it} \quad (4.32)$$

The above regression equation is also valid with the variables $\ln(\hat{y}_{it})$ and $\ln(\hat{y}_{it-1})$ being measured in their deviation forms. These deviations are taken from their respective average values. Therefore, equation (4.32) can be written as:

$$(\ln \hat{y}_{it} - \mu_t) = e^{-\beta} [\ln(\hat{y}_{it-1} - \mu_{t-1})] + u_{it} \quad (4.33)$$

Squaring and summing equation (4.33), along with the subsequent division by the number of observations n generates the variances of the logged income:

$$\sigma_t^2 \cong e^{-2\beta} \sigma_{t-1}^2 + \sigma_u^2 \quad (4.34)$$

In deriving equation (4.34), the covariance between the error term and $\ln(\hat{y}_{it-1})$ is assumed to be equal to zero. Equation (4.34) illustrates the relationship between the two widely discussed types of the income convergence namely β and σ . The cross-sectional dispersion of income is depicting the overtime decreasing pattern with the given negative value of the β coefficient. Nevertheless, the higher variance of the disturbance term can cause an increasing trend in the spread, indicating σ -divergence. Therefore, Barro and Sala-i-Martin (1990) have rendered β -convergence a necessary

pre-requisite for the σ -convergence. In other words, σ -divergence is plausible with β -convergence but not vice versa.

Subsequently, Lichtenberg (1994) has endorsed the similar relationship between these two concepts of convergence. Utilizing equation (4.35) and based on the estimates of the β coefficient and R^2 of the linear convergence regression, Lichtenberg (1994) has developed the following F-distributed test-statistic for the σ -convergence hypothesis:

$$\frac{\sigma_1^2}{\sigma_T^2} = R^2 / (1 + \beta)^2 \quad (4.36)$$

σ_1^2 and σ_T^2 depict the variances of the log-transformed income in the first and last periods respectively. However owing to the dependency between these two variances, Carree and Klomp (1997) have indicated a bias in the test-statistic and alternatively developed the likelihood ratio and the adjusted ratio of variances test statistics in their following respective forms:

$$T_1 = (N - 2.5) \ln \left[1 + \frac{1(\hat{\sigma}_1^2 - \hat{\sigma}_T^2)^2}{4.(\hat{\sigma}_1^2 \hat{\sigma}_T^2 - \hat{\sigma}_{IT}^2)} \right] \quad (4.37)$$

$$T_2 = \frac{\sqrt{N}(\hat{\sigma}_1^2 / \hat{\sigma}_T^2 - 1)}{2\sqrt{1 - \hat{\pi}^2}} \quad (4.38)$$

More recently, Furceri (2005) has analyzed the causality between these two types of convergence in an alternative manner while utilizing the similar convergence equation i.e. (4.31). Focusing on the β coefficient for a linear regression, the author has derived the following:

$$\text{sign}(\beta) = \text{sign}[\sigma_{t-1}^2 - \sigma_t^2 + \text{var}(\ln(GDP_{t-1}) - \ln(GDP_t))] \quad (4.39)$$

In this equation, the declining pattern of variances over time (σ convergence) will necessarily yield a positive β coefficient in equation (4.30) (β -convergence). Therefore, in the presence of σ -convergence there must always be β -convergence but the latter does not confirm the existence of the former.

This brief discussion on the relationship between β and σ convergence is followed by the analysis of σ -convergence in the following sections.

4.3.2. Methodology and Data

The literature on the σ -convergence has widely considered two alternative measures of dispersion. Some of these studies have utilized the standard deviation of log income (S) e.g. Sala-Martin (1996a and 1996b), Persson (1997), Kangasharju (1998) and Jones (2002). While, the coefficient of variation of absolute income (C) was used in some other analyses [Abramotivz (1986), Holtz-Eakin (1993), Ferreira (2000) and Dawson and Sen (2007)]. Utilizing these variables, the graphical depiction of income dispersion is the most commonly applied method for analyzing the subject. However, the former needs to be supplemented by inferential statistics based analysis for σ -convergence; the evidence for which is less frequent. Moreover, as mentioned above, the majority of the existing test statistics of σ -convergence are based on β -convergence estimations. But the possibility of differences between the trends of these two measures of σ -convergence in their relationships with β -convergence may necessitate a statistical test independent of the β -convergence regression. In this context, a trend regression is a plausible option for analyzing the σ -convergence. Earlier, Streissler (1979) and Grier and Grier (2007) have utilized the linear trend regressions on cross-sectional variance of countries to study the growth diffusion process and σ -convergence respectively. Adapting this methodology, the logarithmic and linear trend equations of the following forms are estimated to evaluate the σ -convergence hypothesis

$$\sigma_t^c = \alpha_0 + \alpha_1 \ln t + \varepsilon_t \quad (4.40)$$

$$\sigma_t^s = \delta_0 + \delta_1 t + \varepsilon_t \quad (4.41)$$

Where σ_t^c and σ_t^s denote C and S based income dispersion respectively and t is a time trend. Negative signs for the estimated α_1 and δ_1 will be indicative of the σ -convergence and vice versa. Keeping in view the graphical trends of the income dispersion, the suitable form of the trend regression is fitted. Utilizing the identical

dataset of part 4.2, the above equations are estimated for all the regions with both C and S and the results are reported in Table 4.3. The discussions of the results for the world sample and the resulting convergence paradox are presented in sections 4.3.3 and 4.3.4 respectively. The analysis of σ -convergence for various categories of the world sample is illustrated in section 4.3.5.

4.3.3. σ -convergence for the World Sample

Beginning with the full world sample, trends in the dispersion of income and GDP per working age person are illustrated in Figure 4.10. A comparison of different figures has revealed similar patterns of dispersion for the per capita income and the GDP per working age person. The minor differences in the form of a linear trend for the initial parts of the curves reflect the missing observations for the variable of the GDP per working age person. Because, across the decade of 1950s the data for the working age population are only available for the years 1950 and 1955. The identical tendencies of dispersion for the income and GDP per working age person suggest that either of these variables is equally appropriate for the analysis. Hence, further graphical depiction and the entire regression analyses pertain to the variable of GDP per capita only.

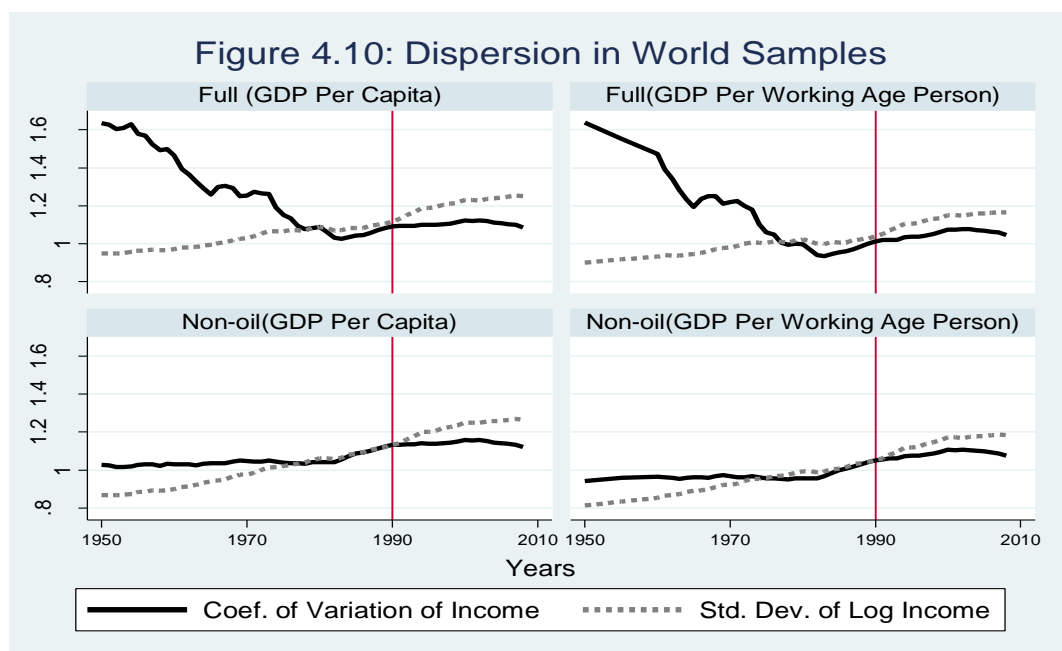


Table 4.3. σ-convergence : Evidence from World GDP Per Capita								
Region/Result	Estimated coefficients using C				Estimated coefficients using S			
	Full sample		Non-oil		Full sample		Non-oil	
	$\hat{\alpha}_1$	R^2	$\hat{\alpha}_1$	R^2	$\hat{\delta}_1$	R^2	$\hat{\delta}_1$	R^2
World	-0.19** (-8.75)	0.86**	0.04** (3.53)	0.56**	0.006** (19.5)	0.97**	0.008** (29.6)	0.98**
Asia	-0.46** (-6.51)	0.84**	0.17** (7.8)	0.90**	-0.0007* (-2.03)	0.08*	0.01** (12.32)	0.94**
Africa	0.17** (3.27)	0.49**	0.17* (3.27)	0.49**	0.005** (8.10)	0.88**	0.005** (8.10)	0.88**
Europe	-0.04** (-7.7)	0.71**	NA		0.0015 (1.79)	0.19**	NA	
Latin America & Caribbean	-0.002 (-0.13)	0.001	NA		0.004** (8.92)	0.82**	NA	
World excluding SSA	-0.22** (-8.8)	0.88**	0.0002 (0.03)	0.00005	0.002** (8.41)	0.65**	0.004** (13.47)	0.93**
High Income	-0.14** (-7.99)	0.83**	0.04** (3.77)	0.62**	-0.07** (-5.6)	0.59**	0.07* (3.4)	0.57**
Upper Middle income	0.06** (5.3)	0.76**	NA		0.08** (5.7)	0.76**	NA	
Lower middle income	0.2** (5.87)	0.84**	0.21** (6.06)	0.85**	0.19** (6.23)	0.86**	0.20** (6.21)	0.84**
Low income	0.23** (4.4)	0.73**	0.24** (4.23)	0.70**	0.14** (4.46)	0.76**	0.14** (4.16)	0.72**
(.) denotes t-statistics; number of observations is similar in each regression and is equal to 59 which is the time period of estimation, 1950-2008. * indicates significance at 5% level, ** indicates significance at 1% level. Significance for R^2 is based on the F-statistics. The σ -convergence is estimated by applying OLS technique with time series data from 1950-2008 on $\sigma_t^C = \alpha_0 + \alpha_1 \ln t + \varepsilon_t$ and $\sigma_t^S = \delta_0 + \delta_1 t + \varepsilon_t$, utilizing the dispersion measures of coefficient of variation of income (C) and standard deviation of logarithmic income (S) respectively. The above t-statistics are based on the Newey-West (HAC) consistent standard errors.								

The graph for C is indicating an overall decreasing pattern in the world income dispersion till the year 1983 while; it has increased afterwards for the subsequent two decades. This higher dispersion during the decades of 1980s and 1990s corresponds with the weak economic performance of the world countries, also indicated by the low world income growth in Table 2.2. The latter is caused by various incidences of high world inflation during 1970s and early 1980s. Contrary to the trend of C , the curve for S is steadily increasing during the entire time-span. The regression results have also endorsed both of the graphical depictions of dispersion.

Continuing with the discussion on the trends in cross-sectional dispersion of income, the second type of world sample analyzed in this section is comprised of the

non-oil countries and is presented in Figure 4.10. Curve of S for the non-oil sample is quite similar with that of the full world sample; gradually increasing throughout the sixty years period. However, C has an approximate constant pattern till 1980s but has increased afterwards till 2000 and has started declining again in the recent decade. Though quite different for the initial decades, respective curves of C for the full and non-oil samples are identical after 1983. Values of C for the initial decades in these two samples differ because of the exceptionally high per capita incomes for a few of the oil rich countries. Correspondingly, with the positive and significant trend coefficients, the estimation results both for C and S of the non-oil world sample are indicating σ -divergence. Therefore, β -divergence is complementing both C and S based σ -divergence evidence for the non-oil sample of the world countries. The analysis for the world sample is followed by the illustrations for its various geographic and income categories in the following.

4.3.4. The Convergence Paradox

A surprising finding from the graphs and the regression estimations of the full world sample is the completely opposite trends with the alternative measures of dispersion. C has an overall declining tendency, while S is increasing. Corresponding to these graphs, the results in Table 4.3 are suggestive of the significant convergence and divergence with C and S respectively. Hence, it is concurrently suggesting σ -divergence in the former case but σ -convergence according to the latter one. It is worth emphasizing here that almost all of the studies on σ -convergence reported in Table 3.8 have utilized either of these measures but not both.

An important query ensuing from these results is the explanation for the opposite trends of income dispersion with C and S . In this context, Dalgaard and Vastrup (2001) have identified and explained the latter by deriving the slopes of these measures as a function of the weighted growth rates of the individual countries. The time derivative of C is equal to:

$$\dot{C} = \frac{1}{n} \sum_{i=1}^n w_c^i g_{yi} \quad (4.42)$$

$$\text{In which } w_c^i \equiv \frac{1}{C} \left[\frac{y_i}{\bar{y}} \left(\frac{y_i}{\bar{y}} - 1 - C^2 \right) \right] \quad (4.43)$$

Similarly, differentiating S with respect to time gives:

$$\dot{S} = \frac{1}{n} \sum_{i=1}^n w_s^i g_{yi} \quad (4.44)$$

$$\text{And } w_s^i \equiv \frac{1}{S} \left[\ln \left(\frac{y_i}{\tilde{y}} \right) \right] \quad (4.45)$$

In the above equations, \dot{C} and \dot{S} represent the time derivatives of C and S respectively. The \bar{y} and \tilde{y} are indicating the arithmetic and geometric means of the absolute income respectively and g_{yi} is denoting the income growth. These weights are utilized by Dalgaard and Vastrup (2001) to explain the differences in these two measures of σ -convergence. Since, the slope of C is a convex function of $\left[\frac{y_i}{\bar{y}} \right]$ while \dot{S} is a concave function of $\left[\frac{y_i}{\tilde{y}} \right]$; countries with lower income values have a larger weight in S compared to that in C . In contrast, given its convex function, C places greater emphasis on the countries with the income values above the mean. Moreover, w_c^i and w_s^i corresponds to the arithmetic and geometric mean respectively. Therefore, considering the *arithmetic and geometric mean inequality* of mathematics, the weight is positive for a larger number of observations in \dot{S} than in \dot{C} .⁶⁷

A comparison of these σ -convergence results with those of β -convergence reported in Table 4.1 signifies the co-existence of significant σ -convergence with that of no β -convergence for the full world sample. *This invalidates all the derived relationships between the two notions of convergence in the previous section maintaining that σ -convergence is implausible without β -convergence.* In contrast, σ -divergence evidence using S is compatible with both the results of Table 4.1 and the causal relationship explained in the section 4.4.1. These results are indicative of the fact that σ -convergence if measured through C may not be related with β -

⁶⁷ See, Bullen (2003) for a proof of the arithmetic and geometric mean inequality.

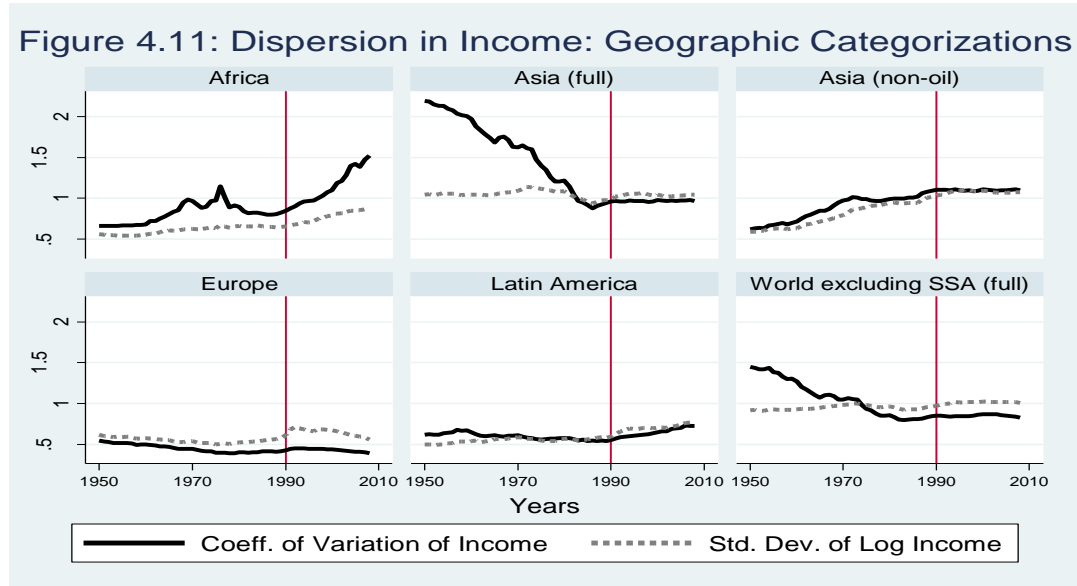
convergence as all the relationships between the two types of convergence, given above, have used S as a measure of σ -convergence.

The above argument can be elaborated further through the derived weights concerning the slopes of C and S discussed earlier and given in equations (4.43) and (4.45) respectively. S with its weight being the concave function of $\left[\frac{y_i}{\tilde{y}} \right]$ renders more importance to the growth rate of the lower income countries than that of rich. This exactly corresponds with the underlying idea of β -convergence. However, the opposite holds for the convex shaped C for which the growth of the rich countries has a higher relative weight. Hence the S based convergence is consistent with β -convergence, but not C based convergence. In the discussion on the measurement of income inequality, Godoy et al. (2004) stated that S is characterized to be more responsive for the income variations among the poor and not amongst rich. Similarly, Atkinson (1970) was of the view that S attaches more weight to the redistributive transfers at the lower side, while the respective weight for C is constant. Hence, C although a measure of income dispersion, may not be a measure of the σ -convergence which is related with the β -convergence. In other words, the relationship between β and σ convergence cannot be generalized for all the measures of the income dispersion suggestive of the σ -convergence.

4.3.5. Intra-Regional Analysis of the σ Convergence

Figure 4.11 shows the income dispersion for the full and non-oil Asian samples with C and S . Since 1950, C has declined throughout for Asia until the middle of 1980s and has an approximately constant pattern afterwards. However, there are some small fluctuations both upwards and downwards in the curve for S . The regression results have confirmed significant σ -convergence for each, C and S . Hence, the full Asian sample is indicating both β and σ convergence. Conversely, the graphical and regression analyses for the non-oil Asian sample have revealed significant σ -divergence with both C and S . This is analogous to the β -divergence indication reported in Table 4.1. As against the previous results, the curves for C and S are roughly parallel alongside the similar regression coefficients for this

particular sample. Reconsidering the weights of C and S pertaining to equations (4.43) and (4.45); smaller differences between the arithmetic and geometric means for the non-oil Asian sample explain some of the similarity in the slopes of these two curves.



Unlike the Asian sample, African countries have exhibited σ -divergence through the significant and positive trend coefficients in the regression estimations of all the categories. Therefore, together with no β -convergence, the African continent has signified an increasing pattern in the income dispersion. Because of the very similar results for the full and the non-oil samples in Table 4.3, the graphical depiction is confined to the full sample only and is presented in Figure 4.11. It is evident from the figure that S has increased gradually over the time-span of 59 years while C has shown a steep rise during the last two decades. The latter occurred parallel in time with the huge increase in the income spread measured as a ratio of the highest income to that of the lowest in the sample [see Table 2.1]. The value of the spread has jumped from 17 in 1990 to 49 and 88 in 2000 and 2008 respectively. However, the number of countries below the per capita income of 1000 dollars has increased from 22 in 1990 to 24 in the year 2000 and the count is still equal to 18 in 2008. Therefore, the presence of a few high income countries in the sample has led to substantial increases both in the income spread and C , while S

has shown a gradual increase because of less variation at the lower end of the income scale.

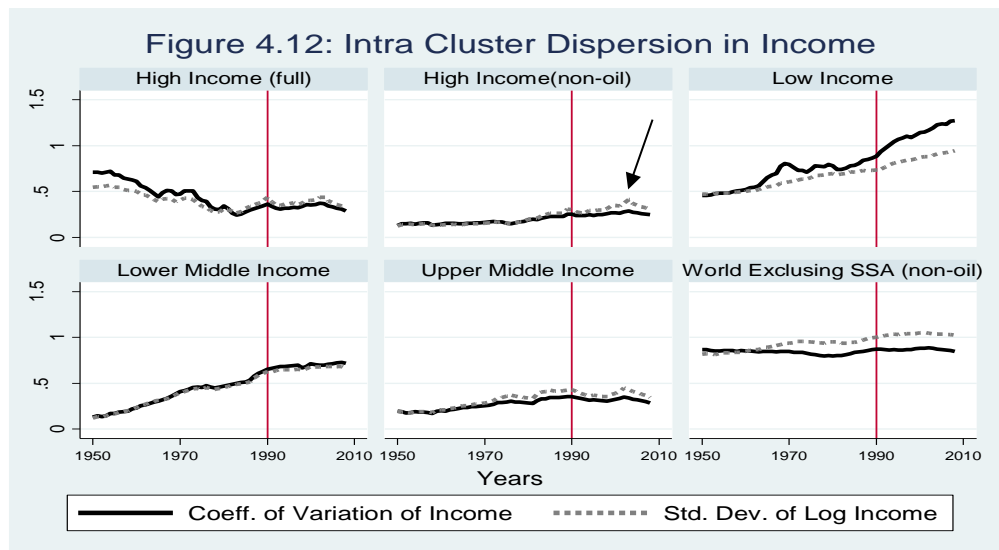
Opposite to the trend for African continent, C for the European region is downward sloping, which is also endorsed by the negative and significant trend coefficient for the region in Table 4.3. The curve for C , as given in Figure 4.11, has increased during the late 1980s till the middle of 1990s. Similarly, S curve has predominantly a declining tendency till 1980 but is indicating a sharp rise afterwards until 1992. Although, the trend coefficient for S in the regression is insignificant. The period of increased dispersion in these graphs is also characterized by low income growth in Europe. Moreover, the differences in the amount of the increases in S and C are due to the fact that the relatively low income countries of the region in 1980 have a higher reduction in their subsequent decade average growth rates.⁶⁸

Contrary to the results of Europe, the Latin American countries have confirmed σ -divergence with S while no convergence is reported using the measure of C . Both curves in Figure 4.11 are roughly similar but since 1983, the S line is above that of C . Furthermore, C is mainly decreasing until 1990 and has increased afterwards. Finally, despite being characterized with opposing evidences on β -convergence, the world sample excluding SSA has similar patterns of income dispersion as that of the full world. The trends of C and S in these two categories are quite alike and the C based regression evidence is illustrating σ -convergence while, the trend coefficient for S is positive and significant. However, its non-oil sample in Figure 4.12 is indicating no σ -convergence using C , along with σ divergence evidence with S [see Table 4.3].

The geography based analysis of the world countries has exemplified more frequent confirmation of σ -convergence using C than with S . The former is indicating that the income dispersion within the regions, as well as across the world, has decreased over the entire sample length. This contrasts with the β -convergence evidence which was confirmed for the full Asian and the European regions only.

⁶⁸ The five low income countries in Europe in 1980 namely, Albania, Romania, Poland, Bulgaria and Hungary have their average income growth rate in 1980s equalling 0.6%, -1.6%, -1.2%, -0.8% and 0.2% respectively. Furthermore, all these five countries are below the arithmetic and the geometric mean of the sample in 1980.

The σ -convergence analysis for the four income categories discussed in the following can also furnish interesting comparisons. The first region in this hierarchy is the high income category and the graphs for the full and the non-oil samples are shown in Figure 4.12. The quite similar graphs for C and S are generally depicting σ -convergence though there are some fluctuations in this declining trend. Likewise, regression results, both with C and S are validating σ -convergence. However, the opposite holds for the non-oil sample with its positive and significant regression coefficients for both the measures; alongside, a persistently increasing pattern of the income dispersion in Figure 4.12. The relatively sharp peak in the later part of S curve is concurrent to the 9/11 event and the subsequent low income growth in this sample which comprises the western offshoots and a few western European countries.⁶⁹



The next category namely the upper middle income group has depicted significant σ -divergence at a decreasing rate both with S and C . Likewise, the curves for S and C in Figure 4.12 are upward sloping though there are some fluctuations in this rising trend during the last three decades in which income growth averaged a low, 1.4%. The last peak in these curves refers to the world recession of early 2000s, when the average income growth for the upper middle income group was just 0.1%. Similarly, the lower middle income group is also indicating

⁶⁹ The non-oil high income countries had an average income growth of 0.2% and 0.8% in 2001 and 2002 respectively.

significant increase in the income dispersion for the full and the non-oil samples. The results for all the categories in Table 4.3 pertaining to each, two samples and two measures of dispersion are quite alike. The similarity in the trend of these two measures can additionally be observed from Figure 4.12 in which C and S have gradually increased over the entire time length.

The last in the list is the low income category with a prior evidence for the β -divergence. Endorsing the latter, this group has also exhibited significant σ -divergence in its various categories. Again the regression results have not explicated any differences amongst them on the basis of the two measures, S and C , and the two sample categorizations, the full and the non-oil ones. The graph in Figure 4.12 is depicting positive trends both for S and C , but the C line is above that of the S one. This corresponds with the African sample in which C is exhibiting greater σ -divergence than S . The distance between these two curves, C and S , indicated a larger increase after 1990s as the ratio between the highest and the lowest incomes within the group has also jumped from 28 in 1990 to 78 and 88 in 2000 and 2008 respectively. Moreover, the larger change is observed in the income levels of the countries at the upper side of the distribution.

One common and important observation in all these graphs in Figure 4.11 and Figure 4.12 pertains to an increasing trend in income dispersion after 1990s which is also indicated by the vertical bar in each graph. As mentioned in part 2.3, the decade of 1990s is characterized with low income growth. This has resulted in an increasing dispersion either in one measure or the other, illustrating σ -divergence. This divergence may be caused by some global shocks during 1980s; yielding subsequent long periods of income divergence across the world.

4.4. DISCUSSION OF RESULTS ON β AND σ CONVERGENCE

All the results pertaining to β and σ convergence discussed in the foregoing are summarized in Table 4.4. To begin with, the world sample has not shown any evidence of β -convergence while its non-oil cluster is diverging. Utilizing an identical methodology, absolute income divergence for the world countries was

Table 4.4. β and σ Convergence: Summary GDP Per Capita (1950-2008)						
Region\Results	Full sample			Non-oil		
	β -convergence	σ -convergence		β -convergence	σ -convergence	
		C	S		C	S
World	No β -convergence	σ -convergence	σ -divergence	β -divergence	σ -divergence	σ -divergence
Asia	β -convergence	σ -convergence	σ -convergence	β divergence	σ -divergence	σ -divergence
Africa	No β -convergence	σ -divergence	σ -divergence	No β -convergence	σ -divergence	σ -divergence
Europe	β -convergence	σ -convergence	No σ -convergence	N/A		
Latin America & the Caribbean	No β -convergence	No σ -convergence	σ -divergence	N/A		
World excluding SSA	β -convergence	σ -convergence	σ -divergence	No β -convergence	No σ -convergence	σ -divergence
High income	β -convergence	σ -convergence	σ -convergence	β -convergence	σ -divergence	σ -divergence
Upper middle income	β -convergence	σ -divergence	σ -divergence	N/A		
Lower middle income	No β -convergence	σ -divergence	σ -divergence	No β -convergence	σ -divergence	σ -divergence
Low income	No β -convergence	σ -divergence	σ -divergence	β -divergence	σ -divergence	σ -divergence
The results for the β -convergence are based on the panel data estimations reported in Table 4.1& 4.2 and those for the σ -convergence are the OLS estimations in Table 4.3. The conclusions for the σ -convergence are based on the individual significance of the trend coefficients.						

earlier concluded by Barro and Sala-i-Martin (1990 & 1992) and Sala-i-Martin (1996a) for the 98 and 110 countries of the world over the time period 1960-85 and 1960-1990 respectively. The values of regression coefficients in these studies were slightly greater than those reported here. Furthermore, the previous literature on the analysis of unconditional income convergence for the world sample has considered the variable of per capita income only. Nevertheless, the conclusions on the absolute convergence using the variable of GDP per working age person are analogous to that of GDP per capita as shown in Tables 4.1 and 4.2.

Considering the geographic categorization, there is no prior empirical analysis pertaining to the absolute income convergence of the Asian region while, the evidence in this study has shown β -convergence and divergence for the full and the non-oil samples respectively. Compared to this, all the estimated results for the African and Latin American regions are insignificant. Parallel findings of no income convergence for Africa and Latin America were earlier confirmed by Murthy and Ukpolo (1999) and Dobson and Ramlogan (2002) respectively. Interestingly, the world sample with the exclusion of SSA region shows β -convergence in all of its estimations asserting that the world is converging, but not SSA because of its persistently poor record of economic growth and development over the period 1950-95. Correspondingly, the absolute income convergence with both the per capita income and the GDP per working age person was illustrated for the European region. This was earlier corroborated by Barro et al. (1991) while, Paci (1997) has concluded absolute convergence for Europe utilizing the variable of labor productivity.

As far as various income categories are concerned, both the high and the upper middle income countries are converging but the rate of convergence is higher for the former as compared to that of the latter. Absolute income convergence among the rich countries was earlier confirmed by the Baumol (1986) and Baumol and Wolf (1989) while, Delong (1988) has concluded the opposite results. Similarly, Baumol (1986) has also corroborated income convergence among the middle income countries though, at a lower rate relative to that for the rich income group. The third category, namely, lower middle income countries has shown significant β -convergence with GDP per working age person but not using the per capita income. Lastly, there is no β -convergence and β -divergence in the full and non-oil samples of

the low income countries respectively. The divergence evidence for the poorer countries was earlier shown by the Baumol (1986) and Delong (1988).

The comprehensive analyses on absolute income convergence, question its theoretical validity. The concept is believed to be one of the implications of the NGM. However, the absolute β -convergence equation for the output per worker in equation (4.25) and its all resulting formulations asserted that given the steady state level of output for a country, there is a negative relationship between the initial value and the subsequent growth. It implies that the convergence equation derived from the NGM necessities for controlling the differences in the steady state levels of income by considering these differences vital. Nevertheless, the assumption of similar steady states for all the countries is the basis for the absolute convergence analysis which appears quite unrealistic. All the empirical analyses in the foregoing have also confirmed little evidence of the cross-country absolute convergence. Additionally, part 2.4 has affirmed that the diversity in the structural characteristics of countries ensured different levels of progress among countries despite having similar geographic/income category or natural resource endowments.

The σ -convergence evidence for the world, Asian, European and Latin American samples are contradictory depending on the specific measure of dispersion utilized for the analysis. But the existing literature based on the measure of S has corroborated σ -divergence or no σ -convergence among the full world sample [Miller and Upadhyay (2002); Barro and Sala-i-Martin (1990)]. Likewise utilizing S , Dobson and Ramlogan (2002) and Paci (1997) have validated no σ -convergence for Latin America and Europe respectively. While Chatterji and Dewhurst (1996) have concluded σ -divergence for the English and Welsh counties and Scottish regions. The African region is characterized with an increasing dispersion though Jones (2002) has confirmed σ -convergence among the 15 nations of Africa. Furthermore, except the high income countries, all the other three income groups have confirmed σ -divergence both with C and S .

4.5. CONCLUSIONS

This chapter is an empirical analysis of the absolute β and σ convergence and their inter-relationship. These notions of convergence were studied using the data of 136 countries over the time-span 1950-2008. Analyses encompass the world sample and its four geographic and four income groups. The graphical and regression methods pertain to each of the variables of per capita income and GDP per working age person. The graphical illustration is based on the scatter graph of the average growth against the basic income in a region. The regression equation for the absolute convergence was derived from the NGM while maintaining a critical assumption of the constancy of steady states for all the countries. Utilizing the cross-sectional and panel data, the non-linear least squares technique is applied to estimate the convergence equation. The full and non-oil samples for some of the categories were still another and important feature of the analysis. It is apparent that the omission of a small number of oil countries can dramatically change the results.

The findings on the β -convergence, in general, have indicated that panel data estimates have more frequent statistical significance than cross-sectional ones. The convergence indication was slightly stronger in the estimations with the GDP per working age person compared to that of the per capita income; though no major difference is observed between the convergence results of these two variables. The world sample and its geographic regions have either indicated divergence or no convergence amongst them except for Asia and Europe, with their significant tendency for the unconditional convergence. On the other hand, the non-oil Asian sample has also indicated β -divergence. The relatively small ‘clubs’ of high and the upper middle income countries are converging while the lower middle income group possesses some evidence in favor of convergence. However, income divergence was confirmed for the low income category. The less frequent evidence for absolute β -convergence confirms the misperception about the concept and suggests that the underlying assumption of constant steady states is false and is not applicable with the actual world data. Hence, there is obvious inference in favor of the conditional β -convergence for the cross-country data analysis against the less plausible option of absolute convergence.

An important perspective of the analyses on β -convergence is that the NGM was misunderstood in its convergence implication because it has not inferred the concept of absolute income convergence. Instead, the Solow-Swan model has introduced the notion of conditional β -convergence which includes country specific steady states for studying the relationship between the initial income and the growth [Mankiw et al. (1992); Sala-i-Martin (1996a)]. Keeping in perspective the inherent and acquired miscellany among the countries, the concept of the conditional convergence seems much plausible. The actual temporal trends of income in different regions or categories have also confirmed the latter. Despite the earlier reference to this fact by few authors, the methodology of the absolute income convergence has been used to investigate the income gap among the countries. In this context, the evidence on lack of absolute convergence is explicated as the poor countries are not catching-up with the rich. However, part 2.4 is indicative of the fact that some low income countries have jumped to the high income category while others are still positioned in the similar status of the low income. These actual trends are also endorsing the significance of differences among countries. Hence, the study of cross-country β -convergence also necessitates an analysis on the conditional convergence.

It is evident from the results that all the possible combinations for β and σ convergence are plausible from the real world data. The σ -convergence is observed both in the presence and the absence of β -convergence while the latter cannot guarantee the presence of the former. More importantly, the conclusions on both the presence of σ -convergence and on the relationship between β and σ convergence are quite different with the two measures of σ -convergence, based on C and S . This questions the significance of σ -convergence in the context of β -convergence, because the absence of σ -convergence does not necessarily imply that there is no β -convergence. This was indicated by the Sala-i-Martin (1996b) with the view that β -convergence pertains to the intra-distributional mobility of countries across time and it may not necessarily indicate a change in the dispersion. Later, the argument was also endorsed by Rowthorn and Kozul-Wright (1998) stating that *σ -convergence is not concerned with catching-up per se*. Furthermore, the nonexistence of σ -convergence does not infer that poor countries have not developed into rich [see Table 4.4]. Nevertheless, some of the literature treats β and σ convergence as

substitutes (e.g. Friedman (1992)). This analysis shows this is invalid. Therefore, the study of β -convergence does not completely correspond with that of σ -convergence.

The convergence empirics consider the σ -convergence the counterpart of the β -convergence and thus it was the focus in the second part of this chapter. Moreover, Friedman's criticism of the β -convergence regressions rendered this even more important. However, this criticism cannot be extended to the panel data formulation of the β -convergence regression, because of its inclusion of the dynamic component in the analysis. The σ -convergence was analyzed for the identical data using the alternative measures of C and S by fitting a logarithmic trend regression. A critical aspect of the relationship between the two types of convergence was the specific measure of dispersion utilized, because some of the results with the two measures of σ -convergence were quite opposite.

This study contradicts the postulation that β -convergence is a necessary condition for the existence of σ -convergence and furnishes an alternative explanation for their relationship. These results are indicative that σ -convergence if measured through C may not be related with the β -convergence, since all the papers which have derived the relationship between the two types of convergence have used the S as a measure of the σ -convergence. Those which have used C have done so on an ad hoc basis. Therefore, the relationship between β and σ convergences cannot be generalized for both the measures of income dispersion suggestive of the σ -convergence, only S not C . This relationship is only plausible with S being the measure of the dispersion. Moreover, changes in the ordinal rankings of countries i.e. β -convergence may not always be concurrent with change in the dispersion of the distribution. Therefore, β and σ convergence are not always related and σ -convergence analysis cannot be utilized to infer for β -convergence.

Chapter 5

STUDY OF CONDITIONAL β -CONVERGENCE

5.1. INTRODUCTION

The study of the absolute convergence hypothesis for an enormously heterogeneous group of world countries encompassing vast diversity in demographics, geographical structures and socio-economic attributes turned out to be implausible. The absolute β -convergence hypothesis was not supported in the bi-variate cross-country regressions. On the other hand, a corresponding intra-country analysis of absolute convergence hypothesis furnished positive evidence for convergence.

Reconsidering the absolute convergence equation and its underlying assumption of constant levels of steady state output per worker for all the countries, Barro (1990) and Mankiw et al. (1992) have revised the concept of absolute convergence while rendering the cross-country differences in steady state levels of income significant. Moreover, Mankiw et al. (1992) have also derived the convergence equation for the neoclassical growth model (NGM) by incorporating the differences in steady state levels of income. Consequently, the concept of *conditional convergence*, as was originally inferred by the Solow-Swan model, was integrated in the convergence empirics. Conditional convergence illustrates a negative relationship between the initial output and its growth rate after controlling for differences in the respective steady states of countries [Sala-i-Martin (1996a)]. This concept implies that countries are converging towards their respective long-run steady state values of per capita income (GDP per worker) rather than towards a uniform income (GDP per worker) level. In other words, conditional convergence affirms similar steady-state paths for countries and the subsequent convergence in the long-run growth rates of per capita income (GDP per worker) based on the assumption of homogenous technological growth rates across countries [Philips and Sul (2007a)]. Therefore, according to the concept, permanent differences between the per capita income (GDP

per worker) levels of countries are usually due to the varying nature of a vast number of underlying parameters of output/income.

This chapter is an attempt to analyze the conditional convergence hypothesis utilizing the cross-country data of 98 countries over the period 1960-2008. The analysis pertains to the world sample and its various categorizations as used in the previous chapter. Conditional convergence is analyzed using the augmented Solow model and a Barro style extended income growth framework, while the system GMM technique for the dynamic panel data is used for the estimations. The primary and original contribution of these empirics will be the study of conditional income convergence for various income categories utilizing the dynamic panel framework. Moreover, this is the first empirical analysis of conditional income convergence for the Asian and the Latin American regions in the context of the augmented Solow model and extended growth regressions. Additionally, it is a pioneering attempt to furnish a comparative analysis of conditional convergence for all the geographic regions utilizing the dynamic panel framework.⁷⁰ Finally, even for these regions which have been previously analyzed, an update of that analysis is presented.

5.2. METHODOLOGY

Beginning with the basic convergence equation (4.27) derived in the last chapter:

$$\ln \left[\frac{y(t)}{y(0)} \right] = (1 - e^{-\beta t}) \ln y^* - (1 - e^{-\beta t}) \ln(y(0)) \quad (5.1)$$

Given this equation (5.1), Mankiw et al. (1992) have developed the conditional convergence equation by substituting the steady state value of the output,

$$y^* = \left[\frac{s}{(n + g + \delta)} \right]^{\frac{\alpha}{1-\alpha}},$$

in the above equation as:

⁷⁰ Karras (2010) analyzed conditional convergence among various geographic regions, though, utilizing simple Solow model with cross-sectional data estimations.

$$\ln \left[\frac{y(t)}{y(0)} \right] = (1 - e^{-\beta t}) \ln \left(\frac{s}{n + g + \delta} \right)^{\alpha/1-\alpha} - (1 - e^{-\beta t}) \ln(y(0)) \quad (5.2)$$

Changing the dependent variable from output per effective worker, y , to output per worker, \hat{y} , generates the following form of the equation:

$$\ln \left[\frac{\hat{y}(t)}{\hat{y}(0)} \right] = gt + (1 - e^{-\beta t}) \ln A(0) + (1 - e^{-\beta t}) \left(\frac{\alpha}{1-\alpha} \right) \ln(s) - (1 - e^{-\beta t}) \left(\frac{\alpha}{1-\alpha} \right) \ln(n + g + \delta) - (1 - e^{-\beta t}) \ln(\hat{y}(0)) \quad (5.3)$$

As already mentioned in chapter 4, $y(t) = \hat{y}(t) / A(t)$. In equation (5.3), the growth rate of output per worker is a function of the determinants of steady state output per worker and that of the initial output per worker. In a cross country regression, the initial level of technology, $A(0)$, and technological growth, gt , are considered parts of the intercept. Hence, the above equation is the *basic Solow model* based regression formulation for the estimation of conditional convergence.

Together with furnishing the framework of analysis for the conditional convergence, Mankiw et al. (1992) while considering the basic Solow model as incomplete have also augmented the NGM with an additional variable, human capital. In the growth literature of that time, the debate on the pivotal role of human capital for economic/per capita income growth was in focus. Specifically, the endogenous growth theory underscores the importance of human capital as a necessary input of production in an economy [Lucas (1988)]. Therefore, with the addition of human capital stock in the basic growth model, an augmented form of the Solow model is developed by Mankiw et al. (1992). Alongside this, a new conditional convergence equation based on the augmented form of the Solow model was also derived and analyzed in their study.

The derivation of the conditional convergence equation for the augmented Solow model is encapsulated as follows. The general form for the augmented Solow model is:

$$Y(t) = H(t)K(t)[A(t)L(t)]$$

$H(t)$ depicts the level of human capital stock.

Its Cobb-Douglas specification is written as:

$$Y(t) = (K(t))^\alpha (H(t))^\eta (A(t)L(t))^{1-\alpha-\eta}$$

The intensive form for the Cobb-Douglas production function is:

$$y(t) = k(t)^\alpha h(t)^\eta \quad (5.4)$$

‘ h ’ is human capital per unit of effective labor which is written as $\frac{H(t)}{A(t)L(t)}$,

and ‘ η ’ illustrates its output share. Time derivatives of physical and human capital per unit of effective labor are equal to:

$$\dot{k}(t) = s_k y(t) - (n + g + \delta)k(t) \quad (5.5)$$

$$\dot{h}(t) = s_h y(t) - (n + g + \delta)h(t) \quad (5.6)$$

In the above equations, s_k and s_h are the respective rates of accumulation for physical and human capital, while an identical rate of depreciation, δ , was assumed for each form of capital. The conversion of the above equations into their growth rate formulations and the subsequent substitutions for the value of $y(t)$ from equation (5.4) results in:

$$\frac{\dot{k}(t)}{k(t)} = s_k \cdot (k(t))^{-(1-\alpha)} \cdot (h(t))^\eta - (n + g + \delta) \quad (5.7)$$

$$\frac{\dot{h}(t)}{h(t)} = s_h \cdot (k(t))^\alpha \cdot (h(t))^{-(1-\eta)} - (n + g + \delta) \quad (5.8)$$

Given that $y(t) = k(t)^\alpha h(t)^\eta$, the growth rate of output per unit of effective labor is equal to:

$$\frac{\dot{y}(t)}{y(t)} = \alpha \frac{\dot{k}(t)}{k(t)} + \eta \frac{\dot{h}(t)}{h(t)} \quad (5.9)$$

The steady state values of physical and human capital per effective worker imply zero growth rates for each variable. Hence, equating the growth rate of these two variables to zero and simultaneous solution of equation (5.7) and (5.8) generates the following steady state values of physical capital and human capital per effective labor:

$$k^* = \left[\frac{(s_k)^{1-\eta} (s_h)^\eta}{(n+g+\delta)} \right]^{\frac{1}{1-\alpha-\eta}} \quad (5.10)$$

$$h^* = \left[\frac{(s_h)^{1-\alpha} (s_k)^\alpha}{(n+g+\delta)} \right]^{\frac{1}{1-\alpha-\eta}} \quad (5.11)$$

Utilizing equation (5.4), the resultant steady state value of output per effective labor is:

$$y^* = \left[\frac{(s_h)^\eta (s_k)^\alpha}{(n+g+\delta)^{\alpha+\eta}} \right]^{\frac{1}{1-\alpha-\eta}} \quad (5.12)$$

As discussed in chapter 4, the derivation of the income convergence equation requires the log-linearization of the equations on growth rates of physical and human capital, which are equations (5.7) and (5.8) respectively. This transformation of equations (5.7) and (5.8) results in:

$$\frac{\dot{k}(t)}{k(t)} = s_k \cdot e^{-(1-\alpha)\ln(k(t))} \cdot e^{\eta\ln(h(t))} - (n+g+\delta) \quad (5.13)$$

$$\frac{\dot{h}(t)}{h(t)} = s_h \cdot e^{\alpha\ln(k(t))} \cdot e^{-(1-\eta)\ln(h(t))} - (n+g+\delta) \quad (5.14)$$

The growth rate of output per effective labor described in equation (5.9) takes the following form after substituting the above values for the growth rate of physical and human capital per effective labor:

$$\frac{\dot{y}(t)}{y(t)} = \alpha \left[s_k \cdot e^{-(1-\alpha)\ln(k(t))} \cdot e^{\eta\ln(h(t))} - (n+g+\delta) \right] + \eta \left[s_h \cdot e^{\alpha\ln(k(t))} \cdot e^{-(1-\eta)\ln(h(t))} - (n+g+\delta) \right]$$

A two dimensional first-order Taylor series approximation of the above equation around the steady state values of k and h yields:

$$\begin{aligned} \frac{\dot{y}(t)}{y(t)} = & \alpha \left[s_k \cdot e^{-(1-\alpha)\ln(k^*)} \cdot e^{\eta \ln(h^*)} - (n + g + \delta) \right] + \eta \left[s_h \cdot e^{\alpha \ln(k^*)} \cdot e^{-(1-\eta)\ln(h^*)} - (n + g + \delta) \right] + \\ & \left[-\alpha s_k \cdot e^{-(1-\eta)\ln(k^*)} \cdot e^{\beta \ln(h^*)} (1 - \alpha) + \eta \cdot s_h \cdot e^{\alpha \ln(k^*)} \cdot e^{-(1-\eta)\ln(h^*)} \cdot \alpha \right] \left[\ln k(t) - \ln k^* \right] + \\ & \left[-\alpha s_k \cdot e^{-(1-\alpha)\ln(k^*)} \cdot e^{\eta \ln(h^*)} \eta - \eta \cdot s_h \cdot e^{\alpha \ln(k^*)} \cdot e^{-(1-\eta)\ln(h^*)} \cdot (1 - \eta) \right] \left[\ln h(t) - \ln h^* \right] \end{aligned}$$

This above equation is simplified using the steady state conditions of equations (5.13) and (5.14). A further simplification generates:

$$\frac{\dot{y}(t)}{y(t)} = -(1 - \alpha - \eta)(n + g + \delta) \left[\alpha (\ln k(t) - \ln k^*) + \eta (\ln h(t) - \ln h^*) \right] \quad (5.15)$$

Since,

$$\frac{y(t)}{y^*} = \left(\frac{k(t)}{k^*} \right)^\alpha \left(\frac{h(t)}{h^*} \right)^\eta, \text{ or}$$

$$\ln y(t) - \ln y^* = \alpha (\ln k(t) - \ln k^*) + \eta (\ln h(t) - \ln h^*)$$

Therefore, the income convergence equation again takes the form of equation (4.25) as:

$$\frac{\dot{y}(t)}{y(t)} = -\beta \left[\ln y(t) - \ln y^* \right]$$

However, according to Mankiw et al. (1992), the value of the convergence coefficient, β , for the augmented Solow growth model is equal to:

$$\beta \equiv (1 - \alpha - \eta)(n + g + \delta) \quad (5.16)$$

Considering the fact that:

$$\frac{\dot{y}(t)}{y(t)} = -\beta \left[\ln y(t) - \ln y^* \right] = \ln \left[\frac{y(t)}{y(0)} \right] = (1 - e^{-\beta t}) \ln y^* - (1 - e^{-\beta t}) \ln(y(0)),$$

which is equation (5.1), the conditional convergence equation can be attained by combining equation (5.1) and (5.12). The equation with GDP per worker as the dependent variable is:

$$\ln \left[\frac{\hat{y}(t)}{\hat{y}(0)} \right] = gt + (1 - e^{-\beta t}) \ln A(0) + (1 - e^{-\beta t}) \ln \left[\frac{(s_h)^\eta (s_k)^\alpha}{(n + g + \delta)} \right]^{\frac{1}{1-\alpha-\eta}} - (1 - e^{-\beta t}) \ln(\hat{y}(0))$$

or

$$\begin{aligned} \ln \left[\frac{\hat{y}(t)}{\hat{y}(0)} \right] = & gt + (1 - e^{-\beta t}) \ln A(0) + (1 - e^{-\beta t}) \left(\frac{\alpha}{1-\alpha-\eta} \right) \ln(s_k) + (1 - e^{-\beta t}) \left(\frac{\eta}{1-\alpha-\eta} \right) \ln(s_h) \\ & - (1 - e^{-\beta t}) \left(\frac{\alpha + \eta}{1-\alpha-\eta} \right) \ln(n + g + \delta) - (1 - e^{-\beta t}) \ln(\hat{y}(0)) \end{aligned} \quad (5.17)$$

An alternative form of the above equation, also derived by Mankiw et al. (1992) is:

$$\begin{aligned} \ln \left[\frac{\hat{y}(t)}{\hat{y}(0)} \right] = & gt + (1 - e^{-\beta t}) \ln A(0) + (1 - e^{-\beta t}) \left(\frac{\alpha}{1-\alpha} \right) \ln(s_k) + (1 - e^{-\beta t}) \left(\frac{\eta}{1-\alpha} \right) \ln(h^*) \\ & - (1 - e^{-\beta t}) \left(\frac{\alpha}{1-\alpha} \right) \ln(n + g + \delta) - (1 - e^{-\beta t}) \ln(\hat{y}(0)) \end{aligned} \quad (5.18)$$

In the above equation, h^* is the steady state level of human capital. The alternative equations (5.17) and (5.18) represent output per worker as a function of the rate of accumulation of human capital, s_h , and the steady state level of human capital, h^* , respectively. Yet, the coefficient on initial GDP per worker, measuring conditional convergence is identical in both of these equations. Moreover, many later empirical studies including Klenow and Rodriguez-Clare (1997) have objected to the secondary enrollment rate/enrollment rate based proxies for human capital [Kalaitzidakis et al. (2001)]. Therefore in our analysis, further discussion on conditional convergence in the augmented Solow model is based only on equation (5.18).⁷¹

The cross-sectional data estimation of these equations by Mankiw et al. (1992) was based on the assumption of cross-country constancy of the initial level of TFP, $A(0)$, and TFP growth, g . As a result, equation (5.18) is written as:

⁷¹ The panel data availability for the variable of human capital stock also facilitates the estimation flexibility for equation (5.18).

$$\ln \left[\frac{\hat{y}(t)}{\hat{y}(0)} \right] = \mu + (1 - e^{-\beta t}) \left(\frac{\alpha}{1 - \alpha} \right) \ln(s_k) + (1 - e^{-\beta t}) \left(\frac{\eta}{1 - \alpha} \right) \ln(h^*) - (1 - e^{-\beta t}) \left(\frac{\alpha}{1 - \alpha} \right) \ln(n + g + \delta) - (1 - e^{-\beta t}) \ln(\hat{y}(0)) \quad (5.19)$$

Owing to the unlikely nature of this assumption, Islam (1995) developed the following panel data formulation for the above equation in which initial TFP and the TFP growth are captured by cross-section and time specific fixed effects respectively:

$$\ln \left[\frac{\hat{y}(\tau)}{\hat{y}(t)} \right] = (1 - e^{-\beta \xi}) \ln A_i(0) + (1 - e^{-\beta \xi}) \left(\frac{\alpha}{1 - \alpha} \right) \ln(s_{kit\tau}) + (1 - e^{-\beta \xi}) \left(\frac{\eta}{1 - \alpha} \right) \ln(h_\tau^*) - (1 - e^{-\beta \xi}) \left(\frac{\alpha}{1 - \alpha} \right) \ln(n_{it\tau} + g + \delta) - (1 - e^{-\beta \xi}) \ln(\hat{y}(t)) + g(\tau - e^{-\beta \xi} t) \quad (5.20)$$

Or

$$\ln \left[\frac{\hat{y}(\tau)}{\hat{y}(t)} \right] = \mu_i + (1 - e^{-\beta \xi}) \left(\frac{\alpha}{1 - \alpha} \right) \ln(s_{kit\tau}) + (1 - e^{-\beta \xi}) \left(\frac{\eta}{1 - \alpha} \right) \ln(h_\tau^*) - (1 - e^{-\beta \xi}) \left(\frac{\alpha}{1 - \alpha} \right) \ln(n_{it\tau} + g + \delta) - (1 - e^{-\beta \xi}) \ln(\hat{y}(t)) + \delta_t \quad (5.21)$$

In this equation, u_i represents the cross-sectional fixed effects and δ_t denotes the time effects. The formulation in equation (5.21) has been a commonly utilized model for the analysis of conditional β -convergence.

Nevertheless, based on Barro (1991), some additional macroeconomic, socio-economic and demographic indicators determining income growth were also considered in the study of growth and conditional convergence. This empirical growth framework was termed the ‘*extended version of neoclassical model*’ by Barro (1998) and later as Barro growth regressions or *extended growth regressions*. The left hand side variable in these regressions is the per capita income growth rather than the GDP per worker, as in the basic and augmented forms of the Solow model by Mankiw et al. (1992). Though the augmented Solow model has equally been applied with both of these income measures and Islam (1995), Caselli et al. (1996) and Bond et al. (2001) have estimated the augmented Solow model using per capita income.

Barro (1998) considered the income growth rate as a function of initial and steady state income levels. The relationship is described as:

$$G_y = f(y_0, y^*) \quad (5.22)$$

Here, G_y is the income growth and y_0 and y^* represent the initial and steady state income levels respectively. The growth regression equation based on equation (5.22) is similar to equation (5.21); except, additional variables are considered as the plausible determinants of steady state levels of per capita income of countries. In addition to the investment ratio and population growth rate, Barro (1991; 1998; 2003) studied the role of the initial level of human capital stock, fertility rate, rule of law, democracy index, government consumption ratio, inflation rate, terms of trade change, trade openness and regional dummies in determining income growth.⁷² In the course of time, more than 60 regressors encompassing political, institutional and economic policy indicators have been considered as determinants of cross-country economic/income growth in the vast empirical growth literature spanning over a decade [Sala-i-Martin, et al. (2004); Sala-i-Martin (1997)].

5.3. VARIABLES AND DATA SOURCES

Utilizing the panel data framework over the period 1960-2008, conditional convergence is analyzed through both the augmented Solow model and Barro type extended growth regressions. The estimations for the former are based on equation (5.21), while a modified version of the same equation, entailing the inclusion of some additional regressors, is utilized for the latter. The availability of data for key variables e.g. the investment ratio and human capital stock, restricts the number of cross-sections to 98 which is much less than the total number of countries, 136, analyzed in the previous chapter on absolute income convergence.⁷³ This is because the earlier analysis only required the data on GDP per capita/GDP per worker.

⁷² The first study by the author involves the cross-sectional data estimations while panel data is utilized in Barro (1998) and Barro (2003).

⁷³ This number does not include those oil countries which are specified and excluded by Mankiw et al. (1992) and in the absolute convergence analysis of the previous chapter.

A critical aspect in the estimation of extended growth regressions is the choice of economic, social, political and institutional indicators to be included as regressors in the model. A priori criterion needs to be specified otherwise it may cause the problem of '*Model Uncertainty*' for these growth regressions as indicated by Temple (2000). According to this, the regression results and their conclusions are dependent on the inclusion or exclusion of certain variables and are not robust and reliable [Temple (2000)]. Owing to this problem, certain methodologies for the sensitivity analyses of such regression results have already been extended and are applied to the income growth regressions as well [Leamer (1985); Levine and Renelt (1992); Sala-i-Martin (1997); Temple (2000); Sala-i-Martin et al. (2004)]. Because of these issues, the variables for the extended income growth regression in the analysis are specified keeping in perspective: i) the pioneering studies by Barro, ii) panel data availability for a large cross-section of countries over the aforementioned time span and iii) a set of particular variables indicated by Sala-i-Martin (1997) and Sala-i-Martin, et al. (2004) in a robustness analysis pertaining to about 60 and 67 growth regressors respectively. Apart from the investment ratio, population growth, initial level of human capital stock and a few regional dummies, the additional regressors for the growth model are the inflation rate, the government consumption ratio, trade openness, life expectancy, the fertility rate, institutional quality index and a democratic regime index.⁷⁴

Keeping with the tradition of the previous literature on long-run growth and income convergence, five yearly intervals are used for the panel data resulting in a total of 10 time-series observations for each country. The intervals are 1960-65, 1965-70,....., 2005-2008. The growth rates of GDP per capita/GDP per worker are calculated over these five year' periods. Some of the regressors of the model e.g. the investment ratio, population growth, inflation rate, government consumption ratio, and trade openness are measured as non-overlapping averages for these intervals. In

⁷⁴Sala-i-Martin, et al. (2004) reported some other robust regressors for growth models, namely, malaria prevalence, ethno-linguistic fractionalization, fraction of tropical area, density of coastal population and the fraction of GDP in mining, which were also considered for income growth models in this study. However, there was no panel data for malaria prevalence, ethno-linguistic fractionalization and density of coastal population though, these three variables in reality, are unlikely to remain constant over a 50 years' time span for the sample countries. While, relatively large number of missing observations for the panel data and/or non-robust and insignificant coefficients in all the estimations for the fraction of GDP in mining and fraction of tropical area ended up in their exclusion from final reported results.

particular this is to minimize the substantial annual fluctuations which can affect these variables. However, values for human capital stock, fertility rate, life expectancy, institutional quality index and democratic regime index are taken at the beginning of the interval period. This is because, data for the human capital and the institutional quality index is only available every five years; while, the initial values for these variables also facilitates their exogenous treatment. Furthermore, also keeping with the tradition of the majority of the earlier literature, including Islam (1995) and Mankiw et al. (1992), the sum of technological growth and depreciation rate ($g + \delta$) is taken as 5% in generating the series of $(n_{it} + g + \delta)$.⁷⁵

Unlike the earlier literature on the empirics of convergence, the variable of human capital is measured as human capital per worker rather than the human capital stock. Keeping in perspective equations (5.4) and (5.11), this form of the variable appears to be more plausible and also compatible with the regressand namely, the GDP per worker. Since, the steady state value of output per worker, through which the conditional convergence equation for the augmented Solow model is derived, is also a function of human capital per worker. Further, considering it a better approach, Bils and Klenow (2000), Hall and Jones (1999), Bosworth and Collins (2003) and Baier et al. (2006) have also utilized this form of the human capital variable in their analyses on cross-country income growth. More importantly, this method makes use of the micro-economic literature on Mincerian earnings function and considers a log-linear relationship between human capital and growth [Cohen and Soto (2007) and Bergheim (2008)]. The human capital variable is constructed through the human capital stock measured as the average years of education of population above the age of 15. The equation for human capital per worker is:

$$h_i = e^{\phi(E_i)}$$

ϕ is the returns to education, E , estimated through Mincerian earnings function. Instead of assuming a uniform value for returns to education for all the sample countries, country specific estimates are used for which the data is taken from Psacharopoulos and Patrinos (2004). Corresponding to the variable of human capital

⁷⁵Taking different values of $(g + \delta)$, equaling 7% and 9%, do not change the main results of regression estimations.

per worker for GDP per worker growth, income (GDP per capita) growth is regressed on human capital per person to maintain consistency.

Maintaining the categorizations of previous chapters, the extent of conditional convergence is examined for the aggregate world sample and also the four geographic regions, namely Asia, Africa, Europe and Latin America & the Caribbean.⁷⁶ As far as the income categories defined in the previous chapters are concerned, the study of conditional convergence in the following pertains to the upper middle, lower middle and the low income countries but not to the high income category. The latter is excluded as the sample size for the high income group is rather small, 10, compared to the respective numbers of 13, 21 and 54 for the upper middle, lower middle and low income categories. More importantly, the high income category is exemplifying absolute β -convergence at a fairly robust rate over the period 1950-2008 [see Tables 4.1 and 4.2]; thus making the study of conditional convergence less pertinent. Lastly, the category of the world without SSA was more relevant to the analysis of absolute income convergence, discussed in chapter 4, in which it has also furnished interesting comparisons. However, it is not included in the following empirics on the conditional income convergence because the study of conditional convergence takes account of cross-country differences in socio-economic parameters and therefore, makes the comparison of world countries, where the world excluding SSA countries, less appealing. Hopefully, the variables in this analysis will pick up all or most of the differences between SSA and the rest of the world countries.

The list of both, the dependent and the explanatory variables for the augmented Solow model and for the extended growth regression analysis is given in Table 5.1. The Table also explicates their data sources and the respective form employed in the analyses. The key data source is the Penn World Tables (PWT) 7.0, while data of World Development Indicators by the World Bank is also used for

⁷⁶ The Asian and the European samples comprises of 19 countries each while the number of countries for the African and Latin American regions is 32 and 22 respectively. Australia, Canada, Fiji, New Zealand, Papua New Guinea, and the USA are not the part of any geographic category included in this analysis, but they are of course part of the world sample.

Table 5.1. Variables, Descriptions and Data Sources

Table 5.1. Variables, Descriptions and Data Sources		
Variable	Variable/Data source	Descriptions
Augmented Solow Model with GDP per worker		
Growth rate of GDP per worker ($\Delta \hat{y}_{i\tau-t}$)	Real GDP per worker (rgdpwok) / PWT 7.0	$\ln \hat{y}_{i\tau} - \ln \hat{y}_{it}, (\tau - t = 5)$
Physical capital stock/Investment ratio ($S_{kit\tau-1}$)	Investment share of real GDP per capita (ki) /PWT 7.0	Average value of variable over the periods t to $\tau - 1$
Growth rate of working population ($n_{wit\tau}$)	Growth rate of number of workers (L) and L is calculated by (rgdpwok/rgdpch)*population/ PWT 7.0	
Steady state level of human capital per worker (h_{it}^*)	Average years of schooling and returns to education /Barro and Lee (2010) and Psacharopoulos and Patrinos (2004)	Value of the variable at the end of the interval, τ
Augmented Solow Model with GDP per capita and Barro Type Extended Growth Regressions		
Growth rate of GDP per capita ($\Delta \hat{y}_{i\tau-t}$)	Real GDP per capita (rgdpch) /PWT 7.0	$\ln \hat{y}_{i\tau} - \ln \hat{y}_{it}, (\tau - t = 5)$
Initial level of human capital per person (h_{pit})	Average years of schooling and returns to education /Barro and Lee (2010) and Psacharopoulos and Patrinos (2004)	Value of the variable at the beginning of the interval, t
Fertility rate (FR_{it})	Fertility rate, (total births per women) /World Development Indicators by World Bank	
Life expectancy (LE_{it})	Life expectancy at birth (total in years) / World Development Indicators by World Bank	
Institutional quality index (IQ_{it})	Economic Freedom of the World index / 2011 Economic Freedom Dataset by the Fraser Institute, Gwartney et al. (2011).	
Democratic regime index (DR_{it})	Democracy and Autocracy indices with the values between -10 and 10/Polity IV Project, Center for Systematic Peace (CSP).	
Growth rate of population($n_{pit\tau}$)	Growth rate of population /PWT 7.0	Average value of the variable over the periods t to $\tau - 1$
Physical capital stock/Investment ratio ($S_{kit\tau-1}$)	Investment share of real GDP per capita (ki) /PWT 7.0	
Trade openness ($TO_{it\tau-1}$)	Openness at constant prices (openk) /PWT 7.0	
Inflation rate ($Inf_{it\tau-1}$)	Inflation (consumer price index, annual %)/World Development Indicators by World Bank	
Government consumption ratio ($GC_{it\tau-1}$)	Government consumption share of real GDP per capita (kg) /PWT 7.0	
The primary data source for this study is PWT 7. In column (2) of the table, the name of each variable in parentheses illustrates its original name given in PWT database. The democratic regime index captures competitiveness and regulation of participation, competitiveness and regulation of executive recruitment and constraints on the executive. The institutional quality index measures regulation of credit, labour and business; access to sound money; legal structure and security of property rights and freedom to exchange with foreigners.		

certain variables.⁷⁷ The two variables with completely different sources are the institutional quality index and the democratic regime index. These two are the only ones in the respective categories of institutional quality and democratic regime which are available with a long and broad panel data context [Munck (2003)].

In addition to the variables mentioned in Table 5.1, dummies for each of sub-Saharan Africa (SSA), Latin America, East Asia and the Spanish colonies are also included in the extended growth regressions. These dummy variables are also indicated as robust growth regressors by Sala-i-Martin et al. (2004). The dummy for SSA countries pertains to their persistent record of low income growth over the last half century, also discussed in the previous chapters [see Table 2.2 and Figure 2.3]. In contrast, the East Asian countries have a remarkable economic performance typified by their exceptionally high economic growth over many years. Since 1960s, the East Asian economies such as China, Hong Kong, Indonesia, South Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand have an average annual growth rate of 8% [Lau and Park (2003)]. The third dummy variable relates to the Spanish ex-colonies which according to Grier (1997, p.47) have lower economic performance because of certain attitudes like *“proclivity toward hierarchical, authoritarian government and religion, a disdain for punctuality and the work ethic, and the lack of public spirit”*.

Table 5.2 presents some of the descriptive statistics such as, minimum, maximum, mean and standard deviation, for all the regression variables pertaining to the world sample and its various categories. The number of observations in each case is reported to provide the information on missing data for each variable within their respective samples. Beginning with the regressand of the model i.e. five years' per capita income growth, $\Delta \hat{y}_{pc_{it-t}}$, the average value for the world sample is 10%. In comparison, the African and Asian samples have the lowest and the highest figures of 5% and 16% respectively. The continent of Europe has a robust growth figure of 13%, but the Latin American countries have a lower average growth equalling 8%. Referring to the income clusters, the upper middle income and the lower middle

⁷⁷ The PWT does report regular annual data on a variable, price of consumption; however, because of its unusual trends compared to the actual inflation trends for different countries, the data for inflation is taken from the World Development Indicators, despite its availability in PWT 7.0.

Table 5.2. Descriptive Statistics: World and Geographic and Income Classifications

Variable/ Sample	$\Delta\hat{y}_{w_{i\tau-t}}$	$\Delta\hat{y}_{pc_{i\tau-t}}$	$s_{kit\tau-1}$	h_{it}	$n_{wit\tau}$	$n_{pit\tau}$	FR_{it}	LE_{it}	IQ_{it}	DR_{it}	$TO_{it\tau-1}$	$Inf_{it\tau-1}$	$GC_{it\tau-1}$
<i>World Sample</i>													
No. of Obs.	980	980	980	980	980	980	970	966	849	901	980	840	980
Minimum	-1.2	-1.2	2.26	0.14	-3.4	-2.78	1	29	0.8	-10	2.4	-27.1	0.35
Maximum	0.66	0.66	87.5	13	9.7	7.5	8	82	9.6	10	433.4	8603.3	41.3
Mean	0.08	0.1	22.9	5.4	2.2	1.9	4	62	6.1	2.2	64.5	41.1	10.1
Std. Dev.	0.16	0.15	10.1	3.2	1.3	1.1	2	12	1.4	7.3	49	390	5.5
<i>Africa</i>													
No. of Obs.	320	320	320	320	320	320	320	320	255	289	320	241	320
Minimum	-1.2	-1.2	2.26	0.15	-3.4	-2.78	2	29	0.8	-9	16.1	-27.1	2.35
Maximum	0.65	0.63	87.5	8.9	6.5	6	8	73	9.6	10	311.6	8603.3	41.3
Mean	0.05	0.05	21.8	2.9	2.6	2.5	6	51	5.4	-2.5	65.9	76.7	10.6
Std. Dev.	0.19	0.19	13.4	2.0	2.6	2.54	1	8	1.2	6.0	35.6	689.6	6.76
<i>Asia</i>													
No. of Obs.	190	190	190	190	190	190	180	180	171	177	190	162	190
Minimum	-0.25	-0.26	4.98	0.15	-0.7	-0.04	1	38	3.1	-10	4.6	-2.3	0.35
Maximum	0.66	0.58	61.2	11.9	9.7	7.5	8	82	9	10	433.4	338.7	27.05
Mean	0.14	0.16	27.2	5.4	2.5	2.1	4	63	6.1	1.03	74.4	13.21	9.1
Std. Dev.	0.14	0.14	10.5	2.9	1.3	1.0	2	10	1.4	7.15	77.7	32.3	4.4
<i>Europe</i>													
No. of Obs.	190	190	190	190	190	190	190	186	171	170	190	184	190
Minimum	-0.29	-0.23	12.8	3.1	-2.6	-1.1	1	65	2.5	-9	2.4	-1.7	3.2
Maximum	0.6	0.66	39.4	12.7	4.4	4.4	4	81	8.9	10	305.1	208.4	17.9
Mean	0.12	0.13	23.9	8.3	1	0.6	2	74	7.2	8.1	64.4	7.7	9.2
Std. Dev.	0.12	0.11	5.06	1.9	1.05	0.6	1	3	1.2	4.8	46.7	16.8	2.7

Variable/ Sample	$\Delta \hat{y}w_{i\tau-t}$	$\Delta \hat{y}pc_{i\tau-t}$	$s_{kit\tau-1}$	h_{it}	n_{witr}	$n_{pit\tau}$	FR_{it}	LE_{it}	IQ_{it}	DR_{it}	$TO_{it\tau-1}$	$Inf_{it\tau-1}$	$GC_{it\tau-1}$
Latin America													
No. of Obs.	220	220	220	220	220	220	220	220	198	210	220	197	220
Minimum	-0.48	-0.41	3.7	0.8	0.3	-0.25	2	42	2	-10	8.6	0.12	2.3
Maximum	0.44	0.43	41.9	9.7	7.1	3.8	8	79	9.2	10	191.7	2414.3	40.2
Mean	0.05	0.08	20.7	5.5	2.5	2.0	4	65	5.9	3.3	60.8	61.8	10.3
Std. Dev.	0.14	0.14	6.6	2.1	1.1	0.9	2	8	1.3	6.3	40.7	256	6.0
Upper Middle Income Countries													
No. of Obs.	130	130	130	130	130	130	130	127	117	120	130	120	130
Minimum	-0.27	-0.26	12.4	4.5	-1.25	-0.25	1	57	2.8	-9	13.7	-1.7	3.9
Maximum	0.33	0.42	42.8	12.7	3.9	2.5	6	81	9.1	10	158.1	863.3	17.9
Mean	0.1	0.12	23.1	8.2	1.2	0.8	2	73	7.0	8.2	59.9	25.6	9.3
Std. Dev.	0.11	0.11	4.8	1.8	0.96	0.58	1	4	1.3	4.3	34.1	95.4	2.9
Lower Middle Income Countries													
No. of Obs.	210	210	210	210	210	210	210	209	186	182	210	197	210
Minimum	-0.29	-0.28	9.45	1.3	-1.04	-1.11	1	43	2.3	-9	7.7	-2.3	2.2
Maximum	0.6	0.66	53.1	11.9	7.1	4.4	8	82	9.1	10	433.4	2414.3	22.8
Mean	0.1	0.12	25.5	6.3	2.4	1.8	4	67	6.4	4.2	79.9	37.8	9.0
Std. Dev.	0.14	0.14	8.2	2.4	1.25	1.03	2	9	1.3	6.5	74.3	215.6	4.7
Low Income Countries													
No. of Obs.	540	540	540	540	540	540	530	530	456	509	540	423	540
Minimum	-1.2	-1.2	2.2	0.14	-3.4	-2.8	1	29	0.8	-10	2.4	-27.1	0.35
Maximum	0.66	0.62	87.5	11.6	9.7	7.5	8	78	9.6	10	311.6	8603.3	41.3
Mean	0.07	0.08	22.3	3.6	2.5	2.3	5	55	5.5	-1.2	61.2	55.3	10.9
Std. Dev.	0.18	0.17	12.1	2.4	1.2	1.0	2	10	1.2	6.5	37.05	527.8	6.4
The definitions and explanations for each of these variables are given in Table 5.1. Starting from the 2 nd column, the variables are growth rate in GDP per worker, growth rate in GDP per capita, investment ratio, human capital stock, workers' growth rate, population growth rate, fertility rate, life expectancy, institutional quality, trade openness, inflation rate and government consumption ratio respectively.													

income groups have an average growth of 12% each while the low income countries have the lowest growth figure of 8%. Moreover, the African and low income samples have the largest within group variation as indicated by their standard deviation which may also be attributed to a larger count of countries in each of these categories.⁷⁸ Despite having varying sample sizes, time spans and data sources, these income growth figures are comparable to the ones reported in Table 2.1, particularly in the context of the income growth record for the four geographic regions.

Turning the discussion to the regressors of the growth models, the average figures for the series of investment ratio across various categories in Table 5.2 are between 20.7 and 27.2, for Latin America and Asia respectively. This perhaps may also explain the differences in the respective income growth values of these two regions. The next two variables, namely the fertility rate FR_{it} and population growth, n_{pit} are interrelated. The world sample on average has a population growth of 1.9% with a fertility rate of 4. While, as previously reported in Table 2.2, the highest and the lowest population growth figures pertain to the African and European continents with their respective values of 2.5% and 0.6%. Similarly, the average fertility rates for these two continents are 6 and 2 respectively. The Asian and the Latin American countries have an average population growth of 2.1% and 2% respectively and their respective average fertility rates equal 4 and 2. It is worth mentioning here that the discussions on the variable of growth in GDP per worker, $\Delta \hat{y}w_{it-t}$, and growth in working population, n_{wit} , are omitted because of their similar trends to that of the per capita GDP growth and population growth respectively.

Education and health, respectively illustrated by average years of schooling and life expectancy in Table 5.2, are rendered as the two most important components of the human capital and hence income growth [Barro (1998)]. The average level of attained education over the years 1960-2008 is the highest for Europe and the upper middle income countries with an approximate figure of 8.3 compared to the values of just 2.9 and 3.6 for African and low income countries respectively. The world sample, Asia and Latin America, all have an approximately equal value for the

⁷⁸ The minimum and the maximum individual income growth figures in the world sample are for the Cyprus in 1980s and Democratic Republic of Congo (formerly Zaire) over 2000-05 respectively.

education variable while the figure for the lower middle income countries is 6.3. Though the variable of human capital per worker is derived from the data on average years of schooling, the differences in returns to education in each country may also yield varying estimates for the human capital per worker. Furthermore, the education and health variables are not performing very differently across various samples and the data on life expectancy has a quite similar pattern to that of the years of schooling [see Table 5.2].

Arguably, the contribution of these factors e.g. investment, education, health and many others to per capita income growth of any country may depend on the type and the transparency of governing institutions. The indices of institutional quality and democratic regime are included in the regression models to capture this possible phenomenon. This is consistent with Rodrik (2000, p.5) who has also asserted the importance of various institutions, maintaining “*property rights, regulation, macroeconomic stabilization, social insurance and conflict management*”, for a better economic performance of a country. The institutional quality index is the Economic Freedom of the World (EFW) index encompassing measures on size of government, regulation of credit, labour and business; access to sound money; legal structure and security of property rights; and freedom to exchange with foreigners. This index has also been utilized in previous studies to proxy the quality of institutions in a country e.g. Gwartney et al. (2004), Redek and Sušjan (2005) and Carmignani (2009).

In Table 5.2, the descriptive statistics for the institutional quality index is based on four of the five sub-indices of the EFW, which is to be utilized in the regression estimations.⁷⁹ Here again, the highest average values pertain to the European and upper middle income groups while African and low income countries have the smallest values. In contrast to the trends in the institutional quality index, the democratic regime index has a greater variation across various study samples in Table 5.2. The European and upper middle income countries on average have the highest score of above 8 followed by the lower middle income group and Latin

⁷⁹ The component of size of government is excluded because of a separate regressor on government consumption share. Moreover, the four sub-indices based institutional quality index has larger within sample variation and higher significance for its own and initial GDP per capita coefficient in regression estimations compared to the full index.

American countries. The African and low income categories have negative values for this index, while Asia also has a low value of 1.03 [see Table 5.2].

It is evident from Table 5.2 that no important differences exist between the average values of trade openness across various samples. However, the large absolute values pertain to the particular measurement utilized in the analysis. Analogous to trade openness, the government consumption ratio also illustrates roughly uniform average values for various country groups, varying between 9% to 11%. In contrast to these two series, Table 5.2 signifies price instability through very high values of average inflation for almost all country groups except the single digit value for Europe. These very high averages may be caused by the few unusual inflation figures of above a 1000 percent for some countries over certain varying periods, e.g. Argentina, Bolivia, Brazil, Democratic Republic of Congo and Zimbabwe.

5.4. ESTIMATION TECHNIQUE

The underlying equation for the estimation of augmented Solow model and Barro style growth regression is (5.21), which alternatively can be written as:

$$\begin{aligned} \ln(\hat{y}_{it}) = & \mu_i + (1 - e^{-\beta\xi}) \left(\frac{\alpha}{1-\alpha} \right) \ln(s_{kit}) + (1 - e^{-\beta\xi}) \left(\frac{\eta}{1-\alpha} \right) \ln(h_{it}^*) \\ & - (1 - e^{-\beta\xi}) \left(\frac{\alpha}{1-\alpha} \right) \ln(n_{it} + g + \delta) + e^{-\beta\xi} \ln(\hat{y}_{it}) + \delta_t \end{aligned} \quad (5.23)$$

The above equation is in a dynamic panel framework, which commonly takes the following form in the panel data literature:

$$y_{it} = \mathcal{Y}_{it-1} + \sum_{j=1}^k \beta_j x_{it}^j + \delta_t + \mu_i + \nu_{it} \quad (5.24)$$

Here, y_{it} and \mathcal{Y}_{it-1} are the dependent and lagged dependent variables, while x_{it}^j and β_j denote the explanatory variables and their coefficients respectively. Moreover as defined earlier, μ_i and δ_t depicts the respective fixed effects for cross-sections and time points. Knight et al. (1993), Loayza (1994) and Islam (1995) developed this framework of analysis for the growth and convergence studies. These authors have

estimated equation (5.24) utilizing either the panel data least squares dummy variable technique (LSDV) or the minimum distance method of Chamberlin or both. The LSDV method is frequently utilized in the later empirical analyses on the subject [see Table 3.3]. In the course of time, the consideration of endogenous regressors in these growth models lead to the application of the instrumental variable (IV) technique [Lee et al. (1998); Barro (1998); Barro (2003)]. More recently, the first differenced GMM and system GMM methods have also been utilized to study conditional β -convergence [Caselli et al. (1996); Bond et al. (2001)].

The necessary information underlying an appropriate estimation technique for equation (5.21) can be attained from the literature on the dynamic panel data estimations particularly the studies focusing on large ‘N’ and small ‘T’ panels (as is the scenario in this study). Despite the fact that some of the earlier panel data studies on conditional convergence have utilized the LSDV approach, according to Nickell (1981) the fixed effects estimation of dynamic panel data models gives biased and inconsistent results specifically with a small T. Similar conclusions come from the Monte Carlo experiments of Kiviet (1995) and Judson and Owen (1999) in analyzing various estimators for dynamic panel data models. Furthermore, according to Baltagi (2005), the application of random effects GLS technique on a dynamic panel model also generates biased results.

The second option for the estimation of dynamic panel models is the IV method of Anderson and Hsiao (1982). In this procedure, the first differenced form of the equation is estimated to eliminate the fixed effects. Subsequently, to resolve the problem of correlation between the error term and independent variable, the latter is instrumented with lagged levels of the variable [Anderson and Hsiao (1982)]. Rewriting the dynamic panel data equation (5.24) as:

$$y_{it} = \gamma y_{it-1} + x'_{it} \beta + \delta_t + \mu_i + v_{it} \quad (5.26)$$

x_{it} is a $(K-1) \times 1$ vector of exogenous regressors. Alternatively, the equation is written as:

$$y_{it} = \psi' x_{it} + \delta_t + \mu_i + v_{it} \quad (5.27)$$

$x_{it} = (y_{it-1} \ x'_{it})'$ is a $K \times 1$ matrix. The Anderson and Hsiao (1982) estimator for a panel of $N \times T$ is:

$$\hat{\psi}_{AH} = (Z'X)^{-1}Z'Y \quad (5.28)$$

Here Z and X are the respective matrices for instruments and regressors with the dimensions $K \times N(T-2)$. While with a dimension of $N(T-2) \times 1$, the vector of dependent variables is denoted by Y [Judson and Owen (1999)]. Although this estimator is consistent, it may not be efficient for the reason of not utilizing all the linear moment conditions [Baltagi (2005)]. Specifically, the Anderson and Hsiao's estimators have a large standard deviation in dynamic panels with a small time dimension of $T \leq 10$ [Judson and Owen (1999)].

Based on the first differencing, a more efficient estimator is the linear GMM estimator proposed by Arellano and Bond (1991). This estimator is based on all linear moment restrictions which results in a large number of instruments for its differenced equation. These instruments are derived from all lagged values of the endogenous regressors from period $t-2$ and beyond while for not strictly exogenous explanatory regressors, all lagged values are used. This implies that the current and all lagged values of strictly exogenous regressors can be utilized as instruments. The vector of coefficients for GMM estimator in each case is equal to:

$$\hat{\psi}_{DGM} = (X'ZA_NZ' \ X)^{-1}(X'Z \ A_NZ' \ Y) \quad (5.27)$$

Here X and Y are same as defined previously. According to Arellano and Bond (1991), Z_i is a $(T-2) \times (T-2) [(k-1)(T+1)+(T-1)]/2$ matrix such that

$$Z_i = \text{diag}(y_{i1}, \dots, y_{is} \ x'_{i1}, \dots, x'_{i(s+1)}), (s = 1, \dots, T-2), Z = (Z'_1, \dots, Z'_N)'$$

A_N in equation (5.27) can be estimated either in one or two steps ensuing two alternative estimators known as one and two step GMM estimators. With an estimate of $A_N = (Z'\hat{\Omega}Z)$, the one step GMM estimator can be written as:

$$\hat{\psi}_{DGM1} = (X'Z(Z'\hat{\Omega}Z)^{-1}Z' \ X)^{-1}(X'Z \ (Z'\hat{\Omega}Z)Z' \ Y) \quad (5.28)$$

$\hat{\Omega}$ is the variance-covariance matrix of residuals in the presence of heteroskedasticity. However, the residuals obtained from one-step GMM estimators can be utilized to obtain the two step GMM estimator by substituting their value in equation (5.28) as:

$$\hat{\psi}_{DGM2} = (X'Z(Z'\hat{\Omega}_{\hat{\beta}_1}Z)^{-1}Z'X)^{-1}(X'Z(Z'\hat{\Omega}_{\hat{\beta}_1}Z)Z'Y) \quad (5.29)$$

The two-step GMM estimators can take account of various forms of heteroskedasticity and cross-correlation. Roodman (2009a) referred $\hat{\psi}_{DGM1}$ and $\hat{\psi}_{DGM2}$ as feasible efficient GMM estimators.

In the context of dynamic panel data with small T, a comparative study of the Anderson and Hsiao (1982) estimator to that of the first differenced GMM estimator concluded the latter was the best estimator [Judson and Owen (1999)]. Despite their aforementioned properties and the application in various studies, Blundell and Bond (1998, p. 115) criticized the difference GMM estimators as:

“In dynamic panel data models where the autoregressive parameter is moderately large and the number of time series observations is moderately small, the widely used linear GMM estimator obtained after first differencing has been found to have large finite sample bias and poor precision in simulation studies. Lagged levels of the series provide weak instruments for first differences in this case.”

Similarly, in another study, Blundell and Bond (2000) argued, and verified, that the bias of difference GMM estimators is greater with persistent data like output/GDP.

As an alternative to the difference GMM technique, the authors proposed the system GMM estimators derived from an approach suggested by Arellano and Bover (1995). The system GMM is an extended form of linear differenced GMM estimators attained through exploiting additional linear moment conditions. In this technique, alongside the difference equations, the level forms of the equation are also introduced and the first difference form of the variables is taken as instruments for

these level equations. Bond et al. (2001, p. 9) explain the difference between the two GMM methods as:

“The system GMM estimator thus combines the standard set of equations in first-differences with suitably lagged levels as instruments, with an additional set of equations in levels with suitably lagged first-differences as instruments.”

The one and two step system GMM estimators are identical to the ones in equation (5.28) and (5.29) respectively; except for an addition of (T-3) number of columns to the instruments matrix, Z_i [Blundell and Bond (1998)]. Furthermore, Monte Carlo experiments by Blundell and Bond (1998) confirmed greater efficiency for the system GMM estimators compared to that of the difference GMM.

Because of being a better estimator and considering the small T of our study sample, the growth models in the following analyses are also estimated with the system GMM technique. The same method is also applied for the study of conditional convergence in various regional samples with a small N.⁸⁰ In analyzing the small sample bias properties of dynamic panel data estimators, Hayakawa (2007) concluded system GMM method to be least biased compared to that of the differenced and level GMM. Correspondingly, considering the small samples in the context of empirical growth literature, Soto (2009) also corroborated the greater efficiency and the least bias properties for the system GMM estimators.

Rather than the conventional regression tests, some other tests are part of the system GMM technique to examine these estimations. The Sargan/Hansen tests of over identifying restrictions are used to examine the validity of all instruments in the system GMM estimators. In addition, the difference in Sargan/difference in Hansen tests are utilized to determine the validity and exogeneity of additional instruments for level equations and other exogenous regressors included in the model. Owing to the estimations in first difference form in the system GMM, the autocorrelation of second order is considered problematic and is tested through the *Arellano and Bond test for AR (2) in first difference*.

⁸⁰Since, the system GMM estimation for dynamic panel data requires $N > T$, therefore the excluded category of high income countries does not fulfill this criterion of estimation as well.

Another important test in the panel data models is the test for cross-sectional dependence because the probability of the presence of cross-sectional dependence in panel data models is considered to be quite high [De Hoyos and Sarafidis (2006)]. Specifically in the context of dynamic panel data estimation, the cross-sectional dependence in errors causes inconsistent GMM estimators [see De Hoyos and Sarafidis (2006) for a comprehensive explanation]. However, in the words of Sarafidis et al. (2009), “*no evidence of 2nd order error serial correlation possibly implies no heterogeneous error cross-section dependence*”. In addition, Sarafidis et al. (2009) proposed a test for heterogeneous cross-sectional dependence in dynamic panel GMM estimators based on the *Difference in Hansen test* for the instruments already mentioned above. The null and alternative hypotheses of this test by Sarafidis et al. (2009) are homogenous vs. heterogeneous cross-sectional dependence respectively. It is worth noting that the homogenous cross-sectional dependence can be corrected by including the time dummies in the regression [Sarafidis et al. (2009)].

The empirical growth models based on equation (5.23) are estimated using the system GMM technique on STATA 12.0 software with *xtabond2* of Roodman (2009a). The augmented Solow model is estimated with both the growth in GDP per worker and the per capita income growth as dependent variables for the reason of facilitating comparison with the results of the Barro growth regression. The GMM estimation of equation (5.24) generates a linear estimator for the non-linear coefficient on conditional convergence in equation (5.23). Therefore, the Delta method is applied, using the STATA command *nlcom*, to obtain the point estimates and standard errors for the rate of conditional convergence, β . However, as income convergence being the key focus of the study, and also because of the numerous existing studies on the topic; the actual shares of physical and human capital are not derived in the following results. Furthermore, using the convergence coefficient, β , the half-life is computed to determine the number of years involved in reducing half of the gap towards the steady state income.

5.5. RESULTS FOR AUGMENTED SOLOW MODEL

The results based on the augmented Solow model for the world sample and for its various categories with both the growth in GDP per worker and per capita income growth are reported in Tables 5.3 and 5.4. Considering these results as a whole, there is no problem of second order autocorrelation nor is there any issue of invalidity or endogeneity of any instruments utilized in difference and/or level forms. Furthermore, the hypothesis of heterogeneous cross-sectional dependence is also rejected for each sample. Finally, keeping in perspective the GMM estimation problems with too many instruments indicted and discussed by Roodman (2009b), the number of instruments in each of the estimation is not very large. Accordingly, none of the reported probability values for the Hansen test of instrument validity are '1' or '0.99', which may imply problematic estimation according to Roodman (2009b).

Focusing on each regressor individually, the positive and almost throughout significant coefficients of physical capital stock may validate the usual and established fact of investment being conducive to both GDP per worker growth and income growth. Across different sample categories, estimated values of these coefficients vary between 0.11 and 0.37. The highest coefficients for physical capital stock pertain to two overlapping categories namely, Latin America and lower middle income, signaling investment as a major determinant of income growth in these clusters. Earlier, De Gregorio (1992) and Gutiérrez (2005) have also confirmed the key role of investment in Latin American growth.

In contrast to the results of physical capital, the variable of human capital per worker is insignificant in all the estimations, while this coefficient also has a negative sign in the Latin American and European samples. The insignificant and sometimes negative impact of human capital on income growth is also confirmed by Kumar (2006), Temple (1999) and Benhabib and Spiegel (1994). According to these authors, measurement problems in the data, insufficient indicators with its focus being only education, *unrepresentative observations* [Temple (1999)] or inappropriate modeling are the likely causes of this impact. De la Fuente and Domenech (2006) and Cohen

Table 5.3. Conditional Convergence with Augmented Solow Model World and Geographic Regions										
Geographic region	World		Africa		Asia		Europe		Latin America	
Variable	GDP per capita	GDP per worker	GDP per capita	GDP per worker	GDP per capita	GDP per worker	GDP per capita	GDP per worker	GDP per capita	GDP per worker
No. of Observations/No. of countries	980/98		320/32		190/19		190/19		220/22	
$\ln(Y_{it}) / \text{Initial GDP per worker (GDP per capita)}$	-0.068** (2.79)	-0.04* (2.19)	-0.08** (2.74)	-0.119* (2.15)	-0.175** (4.95)	-0.133* (2.71)	-0.205** (3.18)	-0.189* (2.44)	-0.161* (2.36)	-0.151** (4.53)
$\ln(s_{kit\tau-1}) / \text{Investment ratio}$	0.20** (6.19)	0.195** (3.92)	0.153** (3.62)	0.193** (4.05)	0.226** (8.88)	0.166* (2.11)	0.269** (2.13)	0.186* (2.17)	0.254** (4.05)	0.273** (4.94)
$\ln(n_{wit\tau-1} + g + \delta) / \text{workers' growth}$ $\ln(n_{pit\tau-1} + g + \delta) / \text{population growth}$	-0.69** (3.91)	-0.41** (3.39)	-0.088 (0.98)	-0.17 (1.03)	-0.34** (3.34)	-0.288* (2.58)	-0.470** (2.64)	-0.77* (2.56)	-0.266 (1.21)	-0.278* (2.33)
$\ln(h_{it}^* / h_{pit}^*) / \text{human capital per worker (per person)}$	0.127* (1.99)	0.036 (0.56)	0.086* (2.12)	0.007 (0.06)	0.19** (5.13)	0.103 (1.0)	0.283 (1.99)	-0.21 (0.57)	0.029 (0.85)	-0.06 (1.76)
Implied β (annual)	0.014** (2.69)	0.01* (2.14)	0.017* (2.62)	0.025* (2.01)	0.038** (4.49)	0.028* (2.52)	0.046** (2.83)	0.042* (2.20)	0.035* (2.16)	0.033** (4.17)
Half-life (years)	50	69	41	28	18	25	15	17	20	21
AR(2) test (H_0 =no autocorrelation)	0.716	0.529	0.736	0.848	0.417	0.414	0.161	0.384	0.373	0.296
Hansen test (H_0 =all instruments are valid)	0.796	0.248	0.497	0.255	0.859	0.720	0.433	0.526	0.299	0.294
Difference in Hansen Test (GMM inst. for levels) (H_0 =exogenous instruments)	0.649	0.517	0.819	0.896	0.828	0.945	0.995	0.527	0.803	0.992
Test for Cross-sectional Dependence	0.530	0.579	0.954	0.940	0.658	0.704	0.819	0.379	0.923	0.935
Notes: Dynamic panel system GMM technique is used to estimate equation (5.21) for each group. Panel data with five yearly intervals over the period 1960-2008 is utilized for the analysis. (.) denotes the t statistics of the respective coefficients. */** indicates significance at 5%/1% levels respectively. p values are reported for the tests of the AR(2), Hansen, difference in Hansen and cross-sectional dependence. Implied rate of convergence (β) is estimated using the Delta Method. The half-life is calculated by the formula, H.L.=ln2/ β .										

Table 5.4. Conditional Convergence with Augmented Solow Model Income Groups						
Income Categories	Upper Middle Income		Lower Middle Income		Low Income	
Variable	GDP PC	GDP per worker	GDP PC	GDP per worker	GDP per capita	GDP per worker
No. of Observations/No. of countries	130/13		210/21		540/54	
$\ln(Y_{it})$ / Initial GDP per worker (GDP per capita)	-0.149** (2.96)	-0.12* (2.40)	-0.196* (2.41)	-0.174** (4.63)	-0.047 (1.92)	-0.077** (2.74)
$\ln(S_{kit\tau-1})$ / Investment ratio	0.157* (2.25)	0.113 (1.28)	0.371** (3.38)	0.288** (3.24)	0.160** (5.50)	0.108** (3.04)
$\ln(n_{wit\tau-1} + g + \delta) / \ln(n_{pit\tau-1} + g + \delta)$ / workers' (population) growth	-0.385* (2.33)	-0.333* (2.32)	-0.277 (1.31)	-0.326* (2.61)	-0.246 (1.17)	-0.146* (1.98)
$\ln(h_{it}^* / h_{pit}^*)$ / human capital per worker (per person)	0.183* (2.82)	0.11 (0.76)	0.168* (2.52)	0.068 (0.77)	0.078 (1.11)	.034 (0.84)
Implied β (annual)	0.032* (2.73)	0.026* (2.25)	0.044* (2.16)	0.038** (4.20)	0.01 (1.88)	0.016** (2.64)
Half-life (years)	22	27	16	18	-	43
AR(2) test (H_0 =no autocorrelation)	0.123	0.149	0.130	0.139	0.208	0.336
Hansen test (H_0 =all instruments are valid)	0.656	0.648	0.642	0.415	0.882	0.909
Difference in Hansen Test (GMM for levels) (H_0 =exogenous instruments)	0.981	0.99	0.99	0.745	0.926	0.998
Test for Cross-sectional Dependence	0.746	0.609	0.814	0.667	0.950	0.970
Notes: see Table 5.3.						

and Soto (2007) have also discussed the measurement problems in the data on human capital stock.⁸¹ However, the system GMM technique, a suggested solution for the measurement errors [Bond et al. (2001)], has already been incorporated in this analysis. Moreover, the additional regressors in the form of health and institutional variables are also included in estimation of Barro type extended growth regression. Thirdly, the consistency of such results for the human capital variable with multiple categorizations of varying sample sizes in Tables 5.3 and 5.4 may validate their robustness and also

⁸¹ Cohen and Soto (2007) have also developed another cross-country dataset on years of schooling for the time-period 1960-2000. However, smaller time-span together with, only, once a decade frequency makes this data less practical compared to the Barro and Lee (2010) dataset on years of schooling utilized in this study.

nullify the possibility of *unrepresentative observations*. Finally, in an attempt to properly model the relationship between human capital and income growth, Benhabib and Spiegel (1994) have suggested an alternative framework based on human capital stock in levels being the determinant of technological growth. However, researchers have identified some problems with this, regarding both its econometric specification and the key conclusions [Gundlach (1999); Pritchett (2001)].

Apart from these explanations related to the methodological issues, Pritchett (2001) extended a theoretical justification for the aforementioned results with respect to the education variable. Pritchett (2001) attributed the negative/insignificant impact of human capital on income growth to low quality of education, low returns because of increased supply and/or to an unfavorable institutional setup of a country. The small coefficients relating to human capital per worker for African and low income countries reported in Tables 5.3 and 5.4 can be rationalized using the latter arguments, specifically with their very low values of average schooling as given in Table 5.2. However, the negligible size of the coefficient for Europe is an exception in this context and requires a further explanation which we now discuss.

An important aspect of these growth estimations is the plausible relationship between the variables of physical and human capital. For example, it is worth noting that the robust coefficient of physical capital stock for Latin America is accompanied with a negative coefficient on human capital stock while, the two coefficients are quite small for the low income countries. The relationship between these two forms of capital has been explained by various studies e.g. Lucas (1993), Romer (1993), Upadhyay (1994), Gundlach (1999), and Grier (2005). Further, according to De la Fuente and Domenech (2006), Soto (2002) and Krueger and Lindahl (2001), the inclusion of both forms of capital in the growth regressions results in underestimation of the coefficient on human capital stock. This is evident from the Tables 5.3 and 5.4 with the coefficient on human capital per worker being much smaller than that of the physical capital stock for the majority of the estimations. Therefore, a problem of multicollinearity may be a probable cause for the insignificant coefficients of the human capital per worker. However, both forms of capital are essential regressors in an income/economic growth framework.

Interestingly, the novel variable of human capital per person has a robust and often significant relationship with the GDP per capita in the augmented Solow model estimations (5 in a total of 8 estimations in Table 5.3 and Table 5.4). This significance pertains to the World, African, Asian, upper middle income and lower middle income groups. Further, in all the estimations for the augmented Solow model, the estimated coefficients for human capital per person are higher than that for human capital per worker in parallel regressions. One possible explanation is the lower multicollinearity between the two regressors, human capital per person and physical capital, since, together with the robust coefficients on human capital per person, all the coefficients on physical capital are significant in their impact on income growth in Tables 5.3 and 5.4. Moreover, the size of the coefficients on physical capital in GDP per worker regressions are slightly lower than those in the GDP per capita regressions in approximately all estimations.

Turning to other regressors, the growth rate of the working population/population has the expected results with its negative impact on GDP per worker growth/income growth. Although, for some samples of developing countries e.g. African, Latin American, low and lower middle income, its coefficient is sometimes insignificant. Many of the earlier growth studies reported in Table 3.3, and others, have also confirmed similar results for the population variables [Ding and Knight (2008); Bond et al (2001); Hoeffler (2000); Islam (1995)].

The key regressor of the analysis, namely the initial value of GDP per worker/income, is negative and significant in almost all the estimations indicating conditional convergence with both, the GDP per worker and per capita income in the majority of the samples in the study. However, the derived rate of convergence (β) is more pertinent than the size of coefficient on the initial income ($\ln(Y_{it})$) in the context of analyses and discussions on conditional convergence. Considering the results for the estimations with GDP per worker in Table 5.3, the world sample is converging towards its steady state income at a rate of 1% per annum. The earlier literature has illustrated varying rates of conditional convergence for the world sample with the estimate of β

ranges between 2% and 6%. However, all of these studies have utilized different methodologies for estimating dynamic panel data equation on conditional convergence [see Table 3.3].

Different geographic regions can have varying rates of conditional convergence depending on their specific structural, demographic and socio-economic parameters and of course, their record of economic performance. The respective rates of conditional convergence in GDP per worker for the African, Asian, European and Latin American regions are equal to 2.5%, 2.8%, 4.2% and 3.3%. According to Table 5.3, the highest conditional convergence rate pertains to the European continent followed by the Latin American region. While, there are no major differences in the conditional convergence rates for the two developing regions of Asia and Africa. The respective lowest and highest rates of conditional convergence of GDP per worker for the African and European regions for the last fifty years may confirm their dissimilar records of economic performance and the three-fold difference in levels of human capital stock (Table 5.2). Alongside, this may illustrate the implications of these (African and European) regions being relatively less developed and developed economies respectively. Notwithstanding the absolute divergence evidence shown in earlier analysis, the continents of Asia also has a reasonable rate of conditional convergence in GDP per worker of 2.8% with a half-life equaling 25 years.

An earlier study on African convergence [Murthy and Ukpolo (1999)] reported a lower rate of conditional convergence for the continent, while weak and insignificant evidence of convergence was reported for the Latin American region [Dobson and Ramlogan (2002)]. But these two studies were based on data with shorter time-spans and have utilized a simple OLS technique. On the other hand, utilizing the methodology of difference GMM for a different sample of countries over the period 1960-90, Tsangarides (2001) has reported a much higher rate of African conditional convergence equaling 5%.⁸² As far as the earlier convergence empirics for Asia are concerned, Evans and Kim (2005) have reported a 2% rate over the period 1960-1992. In their study the

⁸² Generally, the conditional convergence estimates utilizing the first-difference GMM technique are much higher than the ones using the system GMM technique [Bond et al. (2001)].

basic Solow model was estimated using the dynamic random variable technique. Because of different methodologies, the latter results for the Asian sample are not directly comparable to those in Table 5.3.

Table 5.4 presents a more illuminating set of results for the conditional convergence with reference to the three income categorizations. The upper middle income countries have a value of β equal to 2.6% while the lower middle income countries are converging at a higher rate of 3.8%. These two income categories have also illustrated some evidence of absolute convergence in GDP per worker, though, the rate for the lower middle income group was very small [see Table 4.2]. Comparatively, the low income category is characterized with the lowest rate of conditional convergence equaling 1.6%. This figure is contrary to the underlying argument for the conditional convergence that the countries farther from their steady states are likely to converge at a higher rate because of a higher gap between the actual and steady state levels of income. Another distinguishing aspect of the results in Table 5.4 is their completely opposite conclusions compared to a previous study on conditional convergence of various groups by Durlauf and Johnson (1995). These authors have reported the highest and most significant rate of convergence for the poorest group and vice versa. The contrasting conclusions of the latter can be attributed to either a different methodology and/or time period utilized by these authors. Since, Durlauf and Johnson (1995) have applied OLS estimation technique on the augmented Solow model with the cross-sectional data over the period 1960-85.

Referring to the results of the augmented Solow model with per capita income, the income convergence coefficient for the world sample in Table 5.3 is equal to 1.4%. Utilizing the similar methodology, Bond et al. (2001) reported a conditional income convergence rate of 1.7% for the world sample over the period 1960-1985. A comparison of these two results implies a reduced rate of convergence in a 50 years' time period compared to that for the first 25 of those years.⁸³ However, as reported in chapter 3 on literature review, Table 3.3, the application of various other methodologies

⁸³ Similarly, in this study the system GMM estimation of the augmented Solow model for the world sample over the sub-period 1960-85 resulted in a conditional income convergence coefficient of 2.1%.

on the data of world countries has generated much higher rates of conditional income convergence.

Results in Tables 5.3 and 5.4 reveal that the rates of conditional convergence with per capita income are somewhat different than the ones with GDP per worker. The differences are more obvious in terms of the sizes of the coefficients than their significance as all the income convergence coefficients for various geographic categories are higher than the respective convergence rates with GDP per worker with the exception of the Africa. The respective values of the conditional income convergence coefficient (β) for the Asian, European and Latin American regions are 3.8%, 4.6% and 3.5%. However, the lowest degree of income convergence is illustrated by the African region with its coefficient value of 1.7%. Earlier, Hoeffler (2000) has acknowledged the differences in estimated results of the augmented Solow model with GDP per worker and per capita income for the African continent. But, the focus of that study was not on conditional income convergence. As far as various income groups are concerned, the respective rates of income convergence of 3.2% and 4.4% for the upper middle and lower middle income categories in Table 5.4 are higher than the one with GDP per worker. Although, the opposite is true for the low income countries in which there is no significant evidence of income convergence in Table 5.4.

It is worth noting and discussing the difference between the estimated rates of conditional convergence with GDP per capita and GDP per worker for various categories. To explain these varying results on the rates of conditional convergence with the two income measures, we note that GDP per capita is written as $\frac{Y}{P} = \frac{Y}{L} \times \frac{L}{P}$. In this Y is GDP, while L and P denote the total number of workers and the population respectively. GDP per worker has higher rates of conditional convergence for Africa and low income countries because the ratio of workers to population may not have converged for these categories over the period 1960-2008.⁸⁴ In other words, the average value for the workers to population ratio has remained almost constant for the African

⁸⁴ There is no evidence for conditional convergence of the series (workers/pop) over the period 1960-2008 for the African countries. The conditional convergence is estimated utilizing the five yearly panel data with fixed effects. For further estimations and discussions, see Chapter 6.

countries over the study period, being 0.41 in 1960 and 0.42 in 2008. Similarly, the average value of the workers to population ratio for the low income cluster has slightly increased from 0.40 in 1960 to 0.43 in 2008. Therefore, over the time span of 50 years, it has reduced the size of per capita income relative to GDP per worker and may also have affected the rate of income convergence in these two categories. With the constant values of the workers to population ratio, the lower growth of per capita income as compared to that of output per worker is shown in the following. Taking the derivative of $\frac{Y}{P} = \frac{Y}{L} \times \frac{L}{P}$ with respect to time:

$$\left(\frac{Y}{P}\right)' = \left(\frac{Y}{L}\right)' \frac{L}{P} + \left(\frac{L}{P}\right)' \left(\frac{Y}{L}\right)$$

Where, the dash on any variable denotes its derivative. Since, there is virtually no change in the workers to population ratio for the African and low income countries; therefore, the above equation approximately takes the form:

$$\left(\frac{Y}{P}\right)' \approx \left(\frac{Y}{L}\right)' \frac{L}{P}$$

The above equation implies that growth in per capita income, $\left(\frac{Y}{P}\right)'$, is less than the growth in GDP per worker for the African countries.

Further, Table 5.2 also reveals that the average growth in workers is approximately equal to the average population growth rate for the African and low income countries. These are the two categories for which the positive difference between the convergence rates with respect to the GDP per worker and the GDP per capita is the highest. Compared to African and low income groups, the income convergence is higher than that of the convergence in GDP per worker for all other categories, throughout the reported results in Tables 5.3 and 5.4. This can be explained through the already reported positive difference between the average growth rate of workers, n_{witr} , and population growth rate, n_{pitr} , in each of these samples [see Table 5.2]. The increasing

trend in the workers/population ratio may have resulted in a higher rate of income convergence.

Another related and plausible explanation for these differences in convergence rates is related to the trend in the dependency ratios in these regions. According to the World Development Indicators database, the age dependency ratio over the period 1960-2008 has considerably reduced for all the regions in which income convergence rate is higher than that for the GDP per worker. While for the African and low income countries, the dependency ratio in 2008 is approximately equal to that in 1960. Moreover, a fair amount of reduction in the dependency ratios is observed over time for the lower middle income countries.

Finally, the lack of significant evidence of income convergence for the low income countries may indicate that physical capital, human capital and population growth are not the only important determinants for steady state output and hence that of convergence. Some other factors may have a vital role and accordingly need to be incorporated for estimating conditional convergence. Therefore alternative to the augmented Solow model, a more plausible model for per capita income growth can be the Barro style income growth regression. The results and the discussion for the latter are presented in the following section.

5.6. RESULTS FOR EXTENDED GROWTH REGRESSIONS

The results of the extended income growth regressions for the world sample and its various groupings are presented in Tables 5.5 and 5.6. Before proceeding with these results and their discussions, it is worth mentioning that the Barro extended growth framework is adapted here and that there are some differences between the original Barro income growth regressions and the model estimated for this study. One of these is the measurement of the variable on human capital for which the already developed variable of human capital per person is utilized instead of the average years of schooling

as in Barro growth regressions. This alteration facilitates the objective of furnishing a comparative analysis of income convergence for the two different growth models

Table 5.5. Conditional Convergence with Barro Growth Regression				
World and Geographic Regions				
Region	World	Africa	Asia	Europe
No. of Observations/No. of countries	701/91	224/31	154/18	131/17
$\ln(Y_{it})$ / Initial GDP per capita	-0.161** (3.71)	-0.160** (2.77)	-0.08** (3.88)	-0.189** (7.23)
$\ln(s_{it\tau-1})$ /Investment ratio	0.131** (4.01)	0.163** (2.70)	0.072 (1.7)	0.168* (2.60)
$\ln(n_{it\tau-1}+g+\delta)$ / Population growth	0.546 (1.68)	0.182 (1.45)	0.169 (0.94)	-0.479** (3.77)
$\ln(h_{pit})$ / Human capital per person	-0.004 (0.18)	-0.065 (0.76)	0.0008 (0.02)	0.06 (1.21)
IQI_{it} / Institutional quality index	0.039** (3.85)	0.062** (2.75)	0.033 (1.87)	0.015 (0.74)
$\ln(FR_{it})$ / Fertility rate	-0.39** (2.73)	-0.209* (2.78)	-0.21** (3.04)	0.042 (1.59)
DR_{it} (Polity IV)/ Democratic regime index	0.004* (2.22)	-	-	-
$\ln(LE_{it})$ / Life expectancy	-	0.292* (2.00)	-	-
$\ln(Inf_{it\tau-1})$ / Inflation rate	-	-	-	-0.004* (2.23)
$\ln(GC_{it\tau-1})$ / Government consumption ratio	-	-	0.06 (1.94)	-
Dummy for Sub Saharan Africa (SSA)	-0.113** (3.01)	-	-	-
Implied β (annual)	0.035** (3.40)	0.035* (2.53)	0.017** (3.72)	0.042** (6.50)
Half-life (years)	20	20	41	17
AR(2) test (H_0 =no autocorrelation)	0.550	0.721	0.827	0.11
Hansen test (H_0 =all instruments are valid)	0.325	0.359	0.123	0.356
Difference in Hansen Test (GMM for levels) (H_0 =exogenous instruments)	0.433	0.288	0.354	0.99
Difference in Hansen Test (IV) (H_0 =exogenous instruments)	0.466	0.344	0.741	0.778
Test for Cross-sectional Dependence	0.12	0.457	0.353	0.987
Conditional β -convergence is estimated by adding further regressors in equation (5.21). For further notes, see Table 5.3.				

namely, the augmented Solow model and the Barro extended growth regressions.⁸⁵

Table 5.6. Conditional Convergence with Barro Growth Regression				
Various Groups				
Region	Latin America	Upper Middle Income	Lower middle income	Low income
No. of Observations/No. of countries	189/21	104/13	165/19	395/52
$\ln(Y_{it})$ /Initial GDP per capita	-0.179* (2.51)	-0.255** (3.98)	-0.214** (3.63)	-0.146* (2.23)
$\ln(s_{kit-1})$ /Investment ratio	0.224* (2.42)	0.241* (2.24)	0.315** (3.67)	0.224** (3.34)
$\ln(n_{it-1}+g+\delta)$ / Population growth	-0.426 (1.33)	-0.596** (2.89)	-0.307* (2.17)	-0.284 (1.44)
$\ln(h_{pit})$ / Human capital per person	-0.017 (0.29)	0.072 (1.48)	-0.028 (0.59)	0.029 (0.88)
IQI_{it} / Institutional quality index	0.041** (2.66)	0.043* (2.66)	0.056** (2.81)	0.055** (3.92)
$\ln(FR_{it})$ / Fertility rate	-0.020 (0.26)	-0.204* (2.02)	-0.12* (2.31)	-0.064* (2.17)
DR_{it} (Polity IV) / Democratic regime index	-	-	-0.004 (1.15)	-
$\ln(TO_{it-1})$ / Trade openness	-	-	-	-0.101* (2.18)
$\ln(GC_{it-1})$ / Government consumption ratio	-0.196* (2.29)	-	-	-
Dummy for Sub Saharan Africa (SSA)	-	-	-	-0.102 (1.30)
Implied β (annual)	0.039* (2.27)	0.059** (3.42)	0.048** (3.21)	0.032* (2.05)
Half-life (years)	18	12	14	22
AR(2) test (H_0 =no autocorrelation)	0.779	0.356	0.306	0.790
Hansen test (H_0 =all instruments are valid)	0.199	0.726	0.341	0.348
Difference in Hansen Test (GMM for levels) (H_0 =exogenous instruments)	0.665	0.993	0.920	0.531
Difference in Hansen Test (IV) (H_0 =exogenous instruments)	0.821	0.99	0.133	0.110
Test for Cross-sectional Dependence	0.399	0.991	0.794	0.893
Notes: see Table 5.5.				

⁸⁵ The Barro's income growth regression does not include the variable of population growth rate instead, it include fertility rate. However, studies on the augmented Solow model with per capita income have included the latter as a regressor [Bond et al. (2001)]. In an attempt to compare the augmented Solow model and Barro regressions, all the regressors of the augmented Solow model are incorporated in the Barro regressions. Moreover, exclusion of population growth rate from Barro growth model does not significantly alter the results.

Initially, a set of indicators, already reported in Table 5.1, was considered as the plausible regressors for all the estimations. But, it is important to note that all of these variables are not part of the final reported results for each of the aforementioned categories. Besides continuing with the regressors of the augmented Solow model, the institutional quality index and the fertility rate are included in the income growth regression of each category reported in Table 5.5 and Table 5.6. The remaining incorporated regressors vary in different sub-samples depending on the econometric precision of results. To be satisfactory, these require the endorsement of exogeneity and validity tests of instruments, no problem of AR (2) and of course, the individual significance of all the coefficients in the regression. In this context, the inclusion of varying regressors in the income growth regressions of different samples can be justified on the grounds of income growth being uniquely based on the specific history and numerous varying structural, demographic and socio-economic characteristics of each region.

In results reported in Tables 5.5 and 5.6, the coefficient on physical capital stock is throughout positive and also significant in all except one of the samples. Conversely, all the estimated coefficients on human capital are insignificant with either a positive or negative sign. The size and significance of the coefficients on these two forms of capital are not similar to each other for the samples of the Africa, Europe, Latin America, lower middle income, low income, upper middle income and the world. In contrast, estimated results for the Asian sample have lower coefficients for both forms of the capital. The comparatively non-robust/insignificant coefficients for physical capital and human capital per person in Table 5.5 and 5.6 may be the outcome of the inclusion of the additional regressors in these estimations. Some of these regressors like the institutional quality, political regime, inflation rate, trade openness and government consumption can plausibly have a relationship with physical and/or human capital. Furthermore, nothing uncommon is observed in the results for population growth with its negative and significant coefficients for Europe, the upper middle income and lower middle income groups. While, the estimated coefficients on the population variable for the remaining country groups in Tables 5.5 and 5.6 are insignificant.

Moving the discussion towards the additional regressors of the model, the first in the list are two interrelated variables namely the institutional quality and democratic regime indices. A proper institutional setup characterized with a good rule of law has been considered important for economic growth and the development of country and this relationship has been discussed in the literature for quite a long time [see Haggard et al. (2008) for a detailed survey]. According to these studies, institutions with better regulation, security of property rights and efficient policies are conducive to economic growth of a country through facilitating its investment and trade [Barro (1998)]. Alongside the better institutions, the competitive environment in the form of democratic institutions is also believed to be imperative for the economic development [Bardhan (1997); Rodrik (2000); Rodrik and Wacziarg (2006)]. Conversely, the opposite is also argued for the democracy and economic development relationship. In the words of Przeworski and Limongi (1993, p. 51), *“The main mechanism by which democracy is thought to hinder growth are pressures for immediate consumption, which reduce investment”*.

According to the results in Tables 5.5 and 5.6, the institutional quality index is positive and significant in approximately all the estimations; indicating the importance of good quality institutions for income growth specifically in the developing regions. This is because, the highest coefficients on the institutional quality index pertains to the African, lower middle income and low income countries with the respective values of 0.062, 0.056 and 0.055. Conversely, it is insignificant for the relatively developed region in the sample namely, Europe. Similar conclusions of the positive impact of the institutions (rule of law) on income growth were also acknowledged by many papers including Knack and Keefer (1995) and Barro (2003).

The democratic regime index measured by polity IV is not part of the reported results for all samples in Tables 5.5 and 5.6, but for the world sample and lower middle income category. Its coefficient is positive and significant for the world sample but negative and insignificant for the lower middle income group. A positive impact of democracy on income growth is confirmed by Persson and Tabellini (2007) and Jalles (2010). The former study is based on a semi parametric estimation method, while panel

data fixed effects with two stage least squares is utilized by the latter. Contrary to the conclusions of these studies, a negative and weak indirect impact of democracy on income growth is found by Tavares and Wacziarg (2001) who have analyzed the impact of democracy on some plausible determinants of income growth. Furthermore, Dollar and Kraay (2002) have also validated a fairly negative impact of democracy on income growth for poor countries.

The next regressor is the fertility rate which is perceived to have a negative impact on the income growth because a higher number of children imply higher costs of child rearing and consequently a lower increase in capital per worker and production [Barro (1998)]. The fertility rate has a negative impact on the income growth of the regions throughout the Tables 5.5 and 5.6 apart from the European continent for which this coefficient is positive but insignificant. This may be because the negative coefficient on the population growth is of considerable size for the European region in comparison to those for other geographic categories. However, the coefficients on the fertility rate for the World, Africa, Asia, lower middle and low income countries are significant. The Barro type growth framework incorporates both the education and health variables for measuring the human capital. However, life expectancy, a commonly utilized health indicator has significant results only for the African region. This region is believed to be more prone to diseases because of its tropical climate [Moss (2007)]. The coefficient is positive and significant with a fairly robust size confirming the sizeable role of health in the human resource development and hence in income growth of the African region.

The variable of trade openness is part of the income growth model for the low income countries. Trade has always been considered as an engine of growth through its static and dynamic gains for the countries in the form of efficient resource allocation, knowledge transfer and increases in productivity [Thirlwall (2000)]. However, trade liberalization and economic integration can also have a negative impact on economic/income growth [Rivera-Batiz and Xie (1993); Young (1991)]. In Table 5.6, income growth within the low income group is negatively affected by the trade openness and this coefficient is also significant. In the literature on the impact of trade openness on income/economic growth, Rodriguez and Rodrik (2000) have shown very little

evidence for the positive impact of trade liberalization on economic growth. Similarly, Dollar and Kraay (2002) have illustrated a negative, but insignificant, impact of trade openness on income growth of the poor countries. Another plausible explanation for such a relationship between trade liberalization and income growth can be the argument by Andersen and Babula (2008) that, developing countries may lack the complementary inputs necessary to attain the productivity gains from trade liberalization.

The theoretical and empirical literature have confirmed a negative relationship between the inflation rate and economic/income growth through the adverse effects of the former on investment, exports and income distribution [Li and Zou (2002)]. Nevertheless, the presence of unusually large inflation figures in a majority of the regions (see average inflation rate in Table 5.2) has possibly resulted in the poor performance of this variable in the income growth framework, except for Europe. Therefore, inflation is only included in the European sample and it has a negative and significant impact on the income growth of these countries.

Another policy variable, namely the government consumption ratio, has been a frequently utilized regressor for the analysis of long-run income growth [Landau (1983); Barro (1998); Barro (2003)]. On the theoretical front, two famous but opposing arguments are the *crowding out hypothesis* and the *government expenditure multiplier*, help explains the respective negative and positive impacts of government expenditure on economic growth. While, according to Barro (1998), an increase in non-productive government expenditures is unfavourable for the income growth. The empirical literature is inconclusive on this relationship with numerous studies validating both the positive and the negative impacts. In Tables 5.5 and 5.6, the government consumption ratio is positively related with the income growth of the Asian region; but, having an adverse impact on the Latin American growth. The latter coefficient is significant but not the former (which becomes significant in the second income growth regression estimation for the Asian region, reported in Table 5.7). A negative impact of government spending on the economic growth of developing countries was validated by Guseh (1997). Conversely, Bose et al. (2007) have typified an insignificant relationship between government current expenditure and economic growth of the developing region.

However, the growth inducing effect of government current expenditure for the developing countries is corroborated by Ghosh and Gregoriou (2008), specifically, for the fast-growing developing economies [Bayraktar and Moreno-Dodson (2010)]. In an earlier study, a positive and significant impact of government expenditures on the income growth of the Asian region is confirmed by Hakro (2009).

In addition to these regressors, the dummy for SSA is negative and significant for the aggregate world sample illustrating that SSA countries on average have 11.3% less five-yearly income growth compared to other world countries over the period 1960-2008. The insignificant SSA dummy is also negative in the growth regression for the low income category. Besides, the dummy variables for the landlocked countries, the Spanish colonies and East Asian countries dummy variables are insignificant in all of their plausible estimations and are therefore excluded. Similar results of significant SSA dummy and insignificant East Asian dummy for the world sample were also validated by Barro (1998) and Barro (2003).

Finally, turning the discussion towards the central variable of this analysis namely, initial income and the associated derived rate of conditional income convergence (β), all the coefficients in Tables 5.5 and 5.6 are significant with some positive rate of income convergence. The results imply that the Barro type income growth framework better explains the phenomena of growth and convergence than the augmented Solow model. Controlling for additional variables has ensured income convergence for each region, confirming the importance of additional regressors for the income growth and convergence of the countries. The world sample has a conditional convergence rate of 3.5% entailing a half-life of 20 years. The European and Latin American countries are converging towards their respective steady states at the respective rates of 4.2% and 3.9%. The conditional income convergence coefficient for the African sample is robust with the value of 3.5%. Estimating the Barro extended growth regressions for the world sample with a different technique, Caselli et al. (1996) and Barro (2003) have concluded respective convergence rates of 10% and 2.3% for the period 1960-90. The system GMM estimate in Table 5.5 is comparable to that of Barro

(2003); however, application of first difference GMM technique by Caselli et al. (1996) may have overestimated the convergence coefficient [Bond et al. (2001)].

Contrary to the previous results on the rates of income convergence in Table 5.4, the upper middle income countries have the highest rate of conditional income convergence equaling 5.9%. This compares to lower middle income countries converging at a lower rate of 4.8% in the extended growth regressions framework. The lowest value of the convergence coefficient, among various income groups, pertains to the low income countries equaling 3.2%. The respective half-life for the upper middle, lower middle and low income samples is 12, 14 and 22 years. The income convergence coefficients for all these three income categories in the augmented Solow model were lower than the ones in the Barro extended growth model; thus emphasizing the role of additional variables included in the latter analysis. It is worth noting that these results are the first estimates of conditional income convergence for different income categories within the Barro style regression framework.

In the context of income convergence with the extended growth framework, an unusual case is the Asian region. Despite having 16% five-yearly average income growth (Table 5.2) and an income convergence rate of 3.8% in the augmented Solow model, this region typifies the lowest value of β equaling 1.7% in Table 5.5. Keeping in perspective the persistent income growth record of the Asian region over the last half century (Table 2.2), this figure seems quite implausible. A further insight into the convergence analysis for this region reveals a strong relationship between the institutional quality index and the initial income resulting in a lower value of β [see Figure 5.1]. The positive slopes of fitted lines for most of the Asian countries in the scatter graphs of Figures 5.1 confirm the relationship between the institutional quality index and the initial income for many of the Asian countries. Further, an alternative estimation with the exclusion of the institutional quality variable generated an income convergence rate of 4.5% for the Asian region [see Table 5.7].

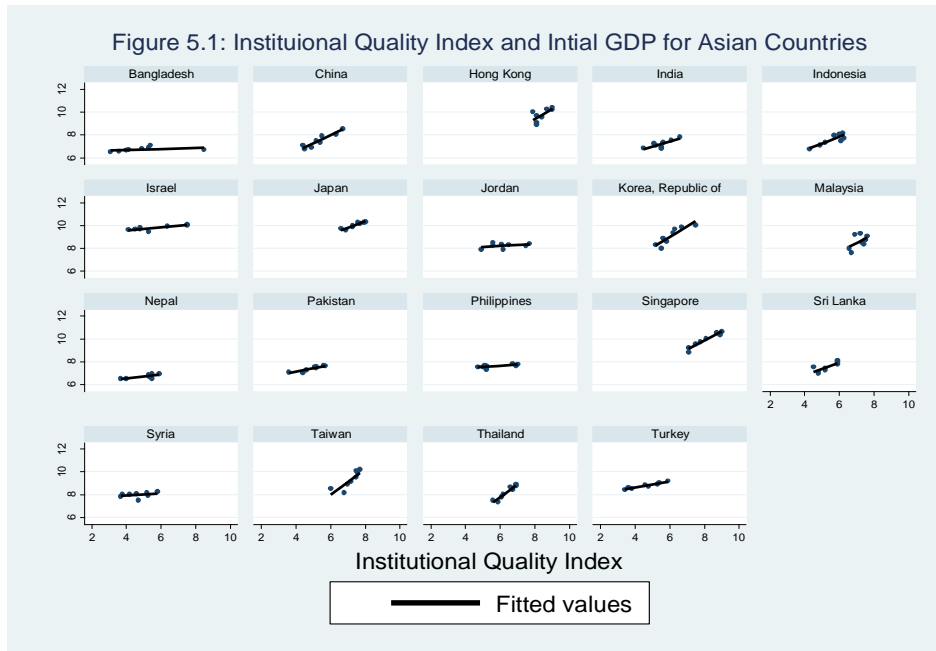


Table 5.7. Alternative Results for Asia with Barro Growth Regression

No. of Observations/No. of countries	167/17
$\ln(Y_{it})$ /Initial GDP per capita	-0.20* (2.53)
$\ln(S_{it\tau-1})$ / Investment ratio	0.09* (2.25)
$\ln(n_{it\tau-1}+g+\delta)$ / Population growth	-0.406 (1.47)
$\ln(h_{pit})$ / Human capital per person	0.26* (2.18)
$\ln(FR_{it})$ /Fertility rate	0.011 (0.11)
DR_{it} (Polity IV) / Democratic regime index	0.001 (0.40)
$\ln(GC_{it\tau-1})$ /Government consumption ratio	0.22* (2.16)
Implied β (annual)	0.045* (2.26)
Half-life (years)	15
AR(2) test (H_0 =no autocorrelation)	0.423
Hansen test (H_0 =all instruments are valid)	0.704
Difference in Hansen Test (GMM for levels) (H_0 =exogenous instruments)	0.995
Difference in Hansen Test (IV) (H_0 =exogenous instruments)	0.968
Alternative results for Asia are estimated by excluding the institutional quality variable from the estimations because of the relationship between initial income and the institutional quality index. For further notes, see Table 5.5.	

5.7. CONCLUSIONS

The estimated rates of conditional convergence for all the samples are reported in Table 5.8. The overall results illustrate that the Barro style extended growth regression is a better framework of analysis for income convergence, although the augmented Solow model also works fairly well with the study of convergence in GDP per worker and GDP per capita. It is worth noting that none of these aforementioned rates of convergence conform to the conventional figure of 2%; therefore, implying a variation in the values for half-life from a low 12 years to a high of 69 years in various estimations.

Table 5.8. Summary of Results on Conditional Convergence			
Convergence type/ Model	Conditional β-convergence (%)		
	Augmented Solow model	Barro style extended growth regression	
Category/Variable	GDP per worker	GDP per capita	GDP per capita
World Sample	1%	1.4%	3.5%
Africa	2.5%	1.7%	3.5%
Asia	2.8%	3.8%	<i>1.7% (4.5%)</i>
Europe	4.2%	4.6%	4.2%
Latin America	3.3%	3.5%	3.9%
Upper middle income	2.6%	3.2%	5.9%
Lower middle income	3.8%	4.4%	4.8%
Low income	1.6%	1% ^a	3.2%
^a denotes insignificant coefficient. These convergence estimates are based on the results in Tables 5.3, 5.4, 5.5 and 5.6.			

The two columns of results with the augmented Solow model depict that the rates of convergence in GDP per capita and GDP per worker are not equal, but rather countries are converging faster in GDP per capita relative to that in GDP per worker, except for the African and low income countries. This can be explained by the constant trend in the dependency ratio or alternatively, with the approximate equal growth of workers and population in the economy. The convergence in GDP per worker is important from the perspective of economics, but welfare and development

considerations put more emphasis on the income convergence. So, the study of both these forms of convergence can shed light on the behavior of economies/countries and their respective parameters in a cross-country framework.

A comparison of the results on the convergence with GDP per capita confirms the role of extended regressors in the income convergence implying that growth and convergence is not solely determined by physical and human capital, but rather a variety of factors have pertinent contributions. The difference in the results of income convergence is noteworthy for the low income countries because there is no significant evidence of income convergence with the augmented Solow model.

An interesting and plausible finding from the results of GDP per worker is the lower rates of convergence for the world sample compared to those of various regions. This illustrates a higher convergence among the more similar categories of regions than for the heterogeneous sample of all world countries. A similar finding is observed in the context of the income convergence estimates, with the exception of the African or/and low income countries. This may indicate that the African (low income) countries are lagging behind in the overall world development; which was also suggested through positive evidence for the absolute income convergence of the world without SSA in the previous chapter.

Among each column of results, Europe, the upper middle and/or lower middle income samples stand out with their higher rates of income convergence. However, the developing samples of Asia and Latin America have a reasonable record of income convergence. Conversely, the low income and African samples have the lowest convergence rates among various income and geographic clusters respectively. This slow rate of conditional convergence for the low income together with the high speed for the upper and lower middle income countries may result in what Quah (1996a) termed as the *twin peaks* in income distribution of the world sample with the two separate groups of

rich and poor countries. However, before reaching this conclusion, further analysis on conditional convergence is required.⁸⁶

Since, conditional convergence affirms countries' movement towards the steady state income level, an important insight into the convergence empirics of these regions is to analyze the behavior of steady state levels of income over the long period. Moreover, further understanding on the varying rates of income convergence across regions also necessitates for the study of sources of income convergence. These two topics will be analyzed in the following chapter of this thesis.

⁸⁶ It is also a pertinent question as to whether these results will still be valid in the years following the current economic crisis

Chapter 6

TOPICS IN CONDITIONAL β -CONVERGENCE

6.1. INTRODUCTION

Analyses on the conditional β -convergence in the previous chapter have illustrated positive evidence in favour of convergence in GDP per worker and GDP per capita for the world sample as a whole and among its various regions. However, one exception in this case is the cluster of low income countries with weak and insignificant evidence for the conditional β -convergence with the augmented Solow model. Further analysis on the income convergence of low income group is worth considering because it is the largest income cluster and comprises all poor countries in 1950. The weak evidence on income convergence may indicate that some poor countries have not developed in the last fifty years.

Conditional β -convergence analyses in the last chapter have also illustrated various rates of convergence in GDP per worker and GDP per capita for different regions and income categories. These empirics will remain incomplete without an insight on the sources of conditional β -convergence which are worth analyzing. In this context, different growth theories have emphasized different sources of income convergence e.g. diminishing returns to physical capital per worker, human capital convergence and/or convergence in total factor productivity (TFP). A study of all these variables can help understand the convergence behaviour of various regions.

Given these considerations, this chapter is an attempt to further analyze the income convergence of the low income group in the second part. A comprehensive analysis on the sources of convergence is presented in the third part. The fourth part is an account of steady state distribution for the world sample over the particular years

along with a comparative analysis for various regions in the sample. The fifth part presents the main conclusions of the chapter.

6.2. REVISITING CONDITIONAL INCOME CONVERGENCE OF LOW INCOME COUNTRIES

This part revisits the conditional income convergence of the low income group with a particular focus on the role of institutional quality and/or initial level of human capital in the income convergence of these countries. Instead of the usual method of regressing the income growth on these two focused variables, this analysis is utilizing a different approach. The low income countries are separately divided into two further categories, based on the median level of initial human capital stock and the median value of the institutional quality indicator. Subsequently, conditional income convergence is analyzed in each of these four clusters of low income countries. This approach is expected to furnish comprehensive insights on the income convergence of low income countries in relation to the human capital stock and institutional quality. The important and original contribution of this analysis is that it is the first study on the comparative analysis of institutional quality and initial human capital stock for the income convergence of poor countries.

6.2.1. Background Literature

As discussed in chapter 2, the role of human capital in economic growth has been emphasized primarily by the endogenous growth theory literature. Lucas (1988) incorporated human capital as one of the variables in the growth model, and is expected to help yield increasing returns. Considering the importance of human capital in economic growth, Mankiw et al. (1992) have also augmented the neoclassical growth model (NGM) by adding the variable of human capital and have empirically validated its significance both in growth and conditional convergence frameworks. More importantly, Barro (1991) has explicitly emphasized the role of initial human capital stock in the

income convergence of countries. According to Barro (1991), the convergence of a poor country towards the rich is conditional on the initial level of human capital stocks. Similarly, in the words of Kyriacou (1991, p. 21), “*laggard countries cannot converge to the economically more advanced countries unless those have relatively abundant levels of initial human capital stock..... the convergence hypothesis holds true only if sufficient levels of per capita human capital stock have been accumulated*”. Analogous views on the role of human capital in the income convergence of poor countries are also discussed by Cohen (1996). In the context of endogenous growth models, Tamura (1991) has developed a model incorporating spillover effects of human capital in investment technology resulting in income convergence both in levels and growth rates. In this model, human capital convergence is the main source for income convergence. In an empirical investigation of Tamura’s proposition using cross-country data, Stamatakis and Petrakis (2006) argued that convergence in higher education is an essential condition for the income growth convergence.

Another important explanation for the relationship between human capital and income growth is through the channel of *technological diffusion*, because human capital is considered a pre-requisite for technological innovations and imitations [Nelson and Phelps (1966); Apergis (2009)]. Baumol (1994) asserted the importance of the initial human capital for the technological development and hence for the income convergence of countries. Alternatively, the role of research and development (R&D) towards total factor productivity (TFP) growth in a country depends on the threshold level of human capital [Xu (2000)]. Specifically, human capital is an important determinant of technological spillovers. Aiyar and Feyrer (2002) have not only confirmed that TFP differences are explaining a key part of income differences across countries but have also validated the vital role of human capital in TFP growth. According to these authors “*international technology spillovers from countries at the frontier to developing countries are facilitated by human capital stocks*” [Aiyar and Feyrer (2002, p. 29)].

There are a large number of studies on the role of institutions in the economic performance of countries. North (1990, 1991) explains the role of institutions in countries and emphasized the importance of institutions for the efficient functioning of

economies through their impact on the incentive structure and transaction costs. In an empirical analysis for 115 economies, Scully (1988) has confirmed the role of institutions in economic growth and the economic efficiency of countries. Hall and Jones (1997, 1999) have argued that institutions and government policies are key in explaining cross-country differences in capital accumulation, productivity and output per worker. Similar conclusions of institutions being a key determinant of cross-country income differences are also extended by Acemoglu and Robinson (2008), Redek and Susjan (2005), Gwartney et al. (2004) and Ali and Crain (2002) and Acemoglu et al. (2001). An interesting and novel aspect of relationship between institutions and economic development is indicated by Comin and Hobijn (2009), who have concluded that “*institutions affect the speed of diffusion of technologies through their effect on lobbying*”. Comin and Hobijn (2009, p. 230) have utilized a dataset of 20 technological diffusions in 23 countries over the time span of two centuries.

More importantly, Keefer and Knack (1997) have specifically discussed the role of institutional variables in explaining income convergence among poor countries. The method utilized in their paper is the same as used in Barro’s style growth framework; that is to incorporate institutional variables as regressors in the convergence regression [Barro (2003)]. The resulting conclusions of the paper by Keefer and Knack (1997) endorse the conditional income convergence; nonetheless, the paper was based on cross-sectional data estimations. Following the similar methodology, a later study by Assane and Grammy (2003) has also indicated the role of institutional quality and institutional efficiency in income growth and conditional income convergence for both the world and less developed countries utilizing cross-sectional data of 110 countries over the period 1960-85.

Another important study on the income convergence of poor countries with reference to economic policies is contributed by Sachs and Warner (1995). Their study concluded that the prevalence of *efficient economic policies* is a crucial determinant of income convergence among the poor countries. Their empirical results have confirmed the absolute income convergence among those developing countries which have a proper institutional set up and are following *plausible economic policies* (as defined in their

study).⁸⁷ Furthermore, growth regressions have also confirmed the significance of the economic policies in their paper. However, the study by Sachs and Warner (1995) was based on cross-sectional data estimations for the period 1970-89.

6.2.2. Methodology and Data

A similar sample of low income countries as discussed in the previous chapter is studied for the period 1960-2008. As mentioned above, the literature has highlighted the role of initial human capital stock in income convergence. However, it may be reasonable to believe that the income growth and convergence of an economy during a specific period depends on the level of institutional quality throughout that period, rather than only at the beginning. Therefore, the low income countries are categorized separately on the basis of human capital stock in 1960 and average value of the institutional quality index over the period 1970-2008 (the period for which these data are available). Both of the categorizations are performed independently to assess the relative significance of initial level of human capital and/or institutional quality in income convergence of low income countries. The data for the human capital stock is the average years of schooling data from Barro and Lee (2010). The data on the institutional quality indicator is sourced from *Economic Freedom of the World Data* by the Fraser Institute. Four of the key components of Economic Freedom of the World index, also known as the institutional quality index, are considered which are measuring regulation of credit, labour and business; access to sound money; legal structure and security of property rights and freedom to exchange with foreigners. Instead of considering the arbitrary threshold values of initial human capital and average institutional quality index, the threshold for each division is the median value of the variable for the sample. The list of countries in each of the clusters is given in Table A-1 in an appendix together with average real per capita income growth of each country over the period 1960-2008.

⁸⁷ These include, civil peace, civil and political rights and an open economy.

It is evident from Table A-1 that countries with either low human capital or poor institutions are having weak average income growth over the last half century. The overall average income growth for these two overlapping groups is around 1% each. Moreover, five and six countries among the low initial human capital cluster and poor institutional quality cluster respectively are characterized with negative average income growth over the study period. It can be inferred from Table A-1, that the high initial human capital countries have performed better than the low initial human capital countries. However, the highest average income growth for the period 1960-2008 pertains to the cluster of countries characterized with better institutional quality and is equal to 2.5%. In this group, the only exception with its negative average income growth is Haiti.

Subsequent to these categorizations, conditional income convergence is estimated among each of these four groupings of low income countries namely, low initial human capital, high initial human capital, poor institutional quality and better institutional quality. The conditional β -convergence is analyzed by estimating equation (5.21) utilizing the system GMM technique with five-yearly panel data for the period 1960-2008.

6.2.3. Results and Discussions

To begin with, Table 6.1 presents the results on the conditional income convergence for the full sample of low income countries for the augmented Solow model but, with the addition of the institutional quality variable. The inclusion of the institutional quality index (IQI) has altered the previous finding of no income convergence of Table 5.4 into significant income convergence at an annual rate of 1.4%; while, institutional quality index is positive and significant. Similarly, physical capital has a positive and significant impact on the income growth of poor countries. In contrast, population growth and human capital per person are insignificant in Table 6.1. Earlier, Keefer and Knack (1997) have also confirmed income convergence among the poor countries with the inclusion of the institutional variable in the convergence regression.

Table 6.1. Conditional Income Convergence in Low income Countries	
No. of Observations/No. of countries	456/53
$\ln (Y_{i,t})$ / Initial GDP per capita	-0.066* (2.10)
$\ln (s_{kit\tau-1})$ / Investment ratio	0.124** (2.99)
$\ln (n_{it} + g + \delta)$ / Population growth	-0.240 (1.33)
$\ln (h^*_{pit})$ / Human capital per person	0.031 (0.57)
IQI_{it} / Institutional quality index	0.082** (3.42)
Implied β (annual)	0.014* (2.03)
Half-life (years)	50
AR(2) test (H_0 =no autocorrelation)	0.166
Hansen test (H_0 =all instruments are valid)	0.599
Difference in Hansen Test (GMM for levels) (H_0 =exogenous instruments)	0.576
Conditional β -convergence is estimated by adding a regressor of institutional quality index in equation (5.21). This equation is estimated by applying dynamic panel system GMM technique. (.) denotes the t statistics of the respective coefficients. *indicates significance at 5% level, ** indicates significance at 1% level. p values are reported for the tests of AR (2), Hansen and Difference in Hansen. Panel data with five yearly intervals over the period 1960-2008 is utilized for the analysis. Implied rate of convergence (β) is estimated using the Delta Method. The half-life is calculated by the formula, $H.L.=\ln 2/\beta$.	

As an alternative to the usual approach of regressing the institutional variable on income growth in the convergence regression, the subsequent analysis focuses on income convergence in various groupings of the low income countries based on the initial human capital and the institutional quality index. The results on the conditional income convergence in these clusters are presented in Table 6.2. According to these results, the coefficient on physical capital is positive and significant in all the estimations while, human capital is throughout insignificant in Table 6.2 and is also negative for the high initial human capital cluster. This insignificant and/or negative impact of human capital on income growth is already explained in detail in the previous chapter. The variable of population growth is either positive or negative, but insignificant for the first

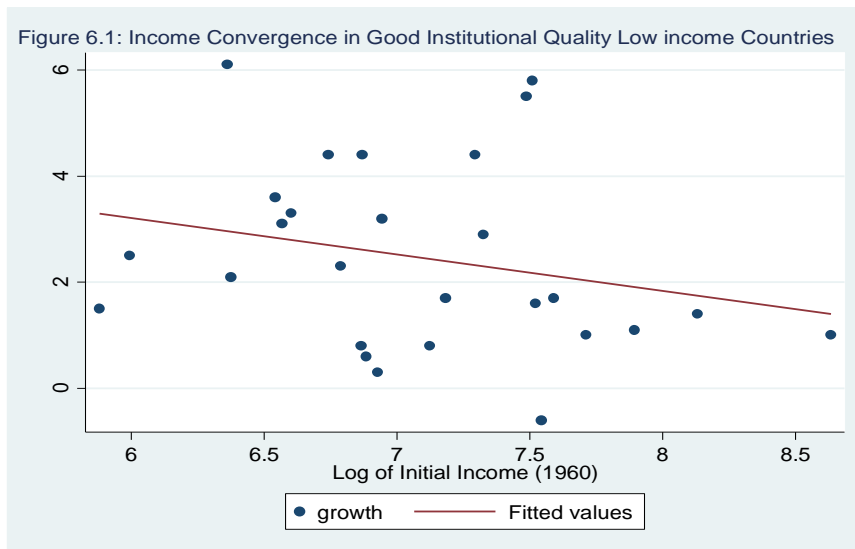
three clusters in Table 6.2; however, it is significantly negative for the group of low income countries with better institutional quality.

Table 6.2. Conditional Income Convergence: Categories of Low Income Countries Augmented Solow Model (1960-2008)				
Category	Low initial human capital	High initial human capital	Poor institutional quality	Better institutional quality
No. of Observations/No. of countries	280/28	260/26	270/27	270/27
$\ln(Y_{i,t})$ / Initial GDP per capita	-0.0239 (0.54)	0.0447 (0.52)	-0.072 (1.12)	-0.104** (2.88)
$\ln(s_{kit-1})$ / Investment ratio	0.148* (2.20)	0.28** (2.79)	0.18* (2.57)	0.218** (3.93)
$\ln(n_{it} + g + \delta)$ / Population growth	0.178 (0.49)	0.148 (0.45)	-0.118 (0.32)	-0.355** (2.80)
$\ln(h^*_{pit})$ / Human capital per person	0.009 (0.03)	-0.038 (0.52)	0.146 (0.74)	0.044 (1.01)
Implied β (annual)	0.005 (0.53)	-0.009 (0.53)	0.015 (1.08)	0.022** (2.73)
Half-life (years)	-	-	-	32
AR(2) test (H_0 =no autocorrelation)	0.121	0.983	0.474	0.515
Hansen test (H_0 =all instruments are valid)	0.360	0.870	0.672	0.538
Difference in Hansen Test (GMM for levels) (H_0 =exogenous instruments)	0.165	0.726	0.788	0.352
Notes: Low income countries are separately divided on the basis of median level of initial human capital and median value of the average institutional quality index. Conditional β -convergence is estimated using equation (5.21) for each of the four samples. For further notes, see Table 6.1.				

Focusing on the results for income convergence in Table 6.2, none of the groups of low income countries are converging except the cluster with better institutions. Coefficients on initial income are insignificant for the poor institutional quality, low and high initial human capital countries, but negative and significant for the better institutional quality cluster implying the annual rate of conditional convergence, β , of 2.2%. This convergence figure for the better institutional quality cluster results in a half-life of 32 years. It is worth noting from Table A-1 that there are many countries which are part of both the high initial human capital and better institutional quality categories. These also include some of the consistently high growing economies in the study

sample, like, China (4.4%), Malaysia (4.4%), South Korea (5.5%), Thailand (4.4%), and Taiwan (5.8%). Still, the high initial human capital category has not shown any evidence of conditional β -convergence.

Further, though not conditional, the β -convergence tendency of the low income group with better institutional quality is also evident from Figure 6.1. The negative fitted line may confirm a negative relationship between initial income and income growth; indicating that the initially poor countries have grown relatively rich over the last half century. This may indicate that better institutions have a significant role in the income convergence of the low income countries and only countries with good institutional quality are able to attain the higher income growth and the convergence towards the steady states.



6.2.4. Conclusions

This part has contributed to the literature of income convergence by studying the role of the initial level of human capital stock and institutional quality towards the catching up of poor countries. The low income countries are not conditionally converging, however only the countries with better institutional quality have converged over the last fifty years. Moreover, initial levels of human capital stock are not contributing towards the

income convergence of poor countries. This contradicts the existing literature emphasizing the direct and indirect role of human capital in income growth and convergence. It may be inferred from the analysis that at low initial levels of development, institutional quality has a higher role in income growth and convergence.

6.3. SOURCES OF CONDITIONAL β -CONVERGENCE

This part is a study of sources of conditional β -convergence for the world sample and for its various regions. Sources of convergence in output per worker and per capita income are analyzed by estimating the convergence rates of physical capital per worker, human capital per worker, TFP and the workers to population ratio.

6.3.1. Growth Models and Sources of Convergence

Different growth models have emphasized different possible sources of income convergence. To begin with, the NGM has rendered diminishing returns to scale or convergence in factor inputs, originally capital per worker, as the key source of convergence given the assumption of technology being exogenous in the model. Sala-i-Martin (1996a) named the convergence approach of the Solow-Swan model as *classical convergence*. As mentioned in Chapter 2, section 2.2.3, the initial endogenous growth models by Romer (1986) and Lucas (1988) have ruled out the possibility of cross-country conditional income convergence because of increasing returns to scale and differences in technological capabilities of countries.

At the outset, Tamura (1991) has developed an endogenous growth model with convergence in levels and growth rates of per capita income. The income convergence in this model is caused by the spillover effects of human capital in investment technology. In other words, human capital convergence is the key source of income convergence. However, this model can only explain the convergence among the developed countries. Criticizing the only focus of convergence literature being capital (physical and human) convergence, Bernard and Jones (1996) have highlighted the role of technological

differences in labour productivity. These authors have also emphasized consideration of the role of technology in the empirical analysis of convergence. Afterwards, Barro and Sala-i-Martin (1997) have developed a framework by combining the elements of the endogenous growth models with the conditional convergence possibility of the NGM. Their model was based on inventions and imitations of technology by the technological leaders and followers countries respectively. According to their model, technological diffusion is resulting in conditional income convergence in the world. In the words of Barro and Sala-i-Martin (1997, p. 1), *'In the long run, the world's growth rate is driven by discoveries in the technologically leading economies. Followers converge at least part way toward the leaders because copying is cheaper than innovation over some range'*. Similarly, technological diffusion is also the basis of income convergence in the Schumpeterian type endogenous growth models [Howitt (2000); Klenow and Rodriguez-Clare (2005); Cordoba and Ripoll (2008)]. In these endogenous growth models, a positive amount of R&D is considered to be a pre-requisite for technology transfer and, therefore, for TFP growth. Thus together with convergence in factor inputs, *technological convergence* or TFP convergence is considered as another main source of income convergence. However, Cordoba and Ripoll (2008) have also emphasized the differences in factor inputs as the key in explaining the cross-country income differences in their endogenous growth model.

Typically the conditional β -convergence framework is based on the augmented Solow model of the form given in Mankiw et al. (1992). The model considered technology as exogenous and convergence in factor inputs as the key source of income convergence. But TFP convergence as a source is also emphasized in the endogenous growth literature and in other studies already mentioned in the above. Therefore, a few studies on income convergence have analyzed the sources of convergence by combining the convergence in factor inputs, physical and human capital per worker, and TFP through a modified regression framework of the augmented Solow model. Primarily, De La Fuente (1995) has analyzed the sources of convergence for the OECD countries by considering the endogenous determination of technological progress in the growth and convergence framework of Mankiw et al. (1992). The possibility of technological catch-

up is studied and the technological progress is taken as a function of R&D expenditures. A later study by Pigliaru (2003) has built upon this methodology to formulate a growth model with combined analysis of sources of convergence. Three of the other studies are by Dowrick and Rogers (2002), Di Liberto et al. (2008) and Di Liberto et al. (2011). The first has utilized the growth accounting method to derive the regression framework for estimating all sources of convergence while, the latter two studies have applied the panel data fixed effects methodology of Islam (1995) and Islam (2003b) to study TFP convergence together with convergence in factor inputs.

6.3.2. Methodology and Data

Given the paper by Dowrick and Rogers (2002), Pigliaru (2003) and Di Liberto et al. (2008), this study utilizes a different approach for the analysis of sources of convergence in GDP per worker and GDP per capita. The paper by Dowrick and Rogers (2002) takes into account the assumption of common population growth for all the countries and proxies the unobservable TFP growth by the growth in output per worker. Moreover, Dowrick and Rogers (2002) have utilized the differenced GMM estimation technique. As mentioned earlier, the system GMM technique is considered a better alternative for estimating the dynamic panel data models. Similarly, Di Liberto et al. (2008) have utilized the fixed effects methodology to capture the unobservable (TFP) and TFP convergence. Moreover, the convergence framework given by Pigliaru (2003) requires the data on R&D expenditures which is not available for a broad sample of countries other than for the OECD.

However, the differences between the NGM and endogenous growth theories regarding the sources of convergence can be rationalized with the observation that the steady state equation for augmented Solow model of Mankiw et al. (1992) is similar to that of the endogenous growth model of Howitt (2000).⁸⁸ In discussing the steady state

⁸⁸ It is important to note that the steady state equation of output per worker of Howitt (2000) is not estimated in its exact form in analyzing the conditional convergence in the previous chapter because of non-availability of a broader set of data on R&D. However, based on the similarity between these two

equation derived by Mankiw et al. (1992), Howitt (2000, p. 839) was of the view that *‘The fact that the same equation can be derived from the present Schumpeterian endogenous growth framework implies that its empirical success does not refute endogenous growth theory in general’*. However, the value of the implied convergence coefficient in the endogenous growth models of Howitt (2000) is lower than that in the NGM.

Rewriting the Cobb-Douglas production function as:

$$Y_{it} = (K_{it})^{\alpha} (H_{it})^{\eta} (A_{it} L_{it})^{1-\alpha-\eta}$$

Y is output, K is the physical capital stock, H is the human capital stock, L is the labour and A is the total factor productivity. α and η are the shares of physical and human capital in output. Its intensive form (per worker form) is:

$$y_{it} = k_{it}^{\alpha} h_{it}^{\eta} A_{it}^{1-\alpha-\eta} \quad (6.1)$$

Since, output per worker is a function of physical capital per worker, human capital per worker and TFP, this study of sources of convergence in the following will analyze the convergence rates for each of these inputs. Rewriting the identity describing the relationship between GDP per worker and GDP per capita:

$$\frac{Y}{P} \equiv \frac{Y}{L} * \frac{L}{P} \quad (6.2)$$

In this equation Y, L and P denote the output, number of workers and population respectively. It may be inferred from equation (6.2) that the convergence of per capita income is a function of both the convergence in output per worker and convergence in the workers to population ratio. Therefore, conditional convergence in the workers to

types of growth models, the previously estimated augmented Solow model based conditional β -convergence rates of output per worker and output per capita may well be compared with the rates of conditional convergence for factor inputs and TFP.

population ratio is investigated to explore the difference between the convergence rates of output per worker and per capita income reported in the previous chapter.

Sources of convergence of GDP per worker and GDP per capita in the following are analyzed by separately estimating the rates of conditional convergence for (i) the capital-labor ratio, (ii) the human capital, (iii) total factor productivity and (iv) the workers to population ratio. In this context, the typical convergence regression equation with five-yearly panel data is estimated separately for each of the variables. As with the concept of conditional convergence, the country specific differences are controlled by applying the fixed effects methodology. The time dummies are also included in the regression to capture the period specific common changes in these variables. The conditional convergence equation takes the form:

$$\ln \left[\frac{x_{i\tau}}{x_{it}} \right] = \mu_i + \tau_t + (1 - e^{-\theta\xi}) \ln(x_{it}) + \varepsilon_{it\tau} \quad (6.3)$$

$x_{i\tau}$ and x_{it} denote the terminal and initial values of the variable in focus over the five yearly panel interval and τ_t and μ_i denotes the time effects and fixed effects respectively. θ is the conditional convergence coefficient and ξ is the time interval or the difference between τ and t . Equation (6.3) is utilized to estimate conditional convergence for the capital-labor ratio, human capital stock, human capital per worker and the workers to population ratio. TFP convergence is analyzed using the TFP convergence framework given in Dowrick and Rogers (2002):

$$g_{i\tau} = g_i + g_t + \phi \ln \left(\frac{A_t^*}{A_{i,t}} \right) \quad (6.4)$$

$g_{i\tau}$ is the growth rate of technology over the time interval τ to t . g_i and g_t are the country specific and time-specific fixed effects respectively. A_t^* and $A_{i,t}$ are the respective TFP levels of the technological leader country and any follower country i at the beginning of the time interval t . The former may well represent the steady state

level of technology in any period t . This implies that ϕ is the rate of conditional TFP convergence of a follower country towards the technological leader country and a positive value of ϕ indicate the conditional convergence. Given the idea of TFP convergence being technological diffusion because of imitation of technology by the follower countries, equation (6.4) may represent a plausible framework for analyzing the TFP convergence compared to that described in equation (6.3). Though, equations, (6.3) and (6.4) are quite similar and generate approximately equal estimates for rates of TFP convergence.

As mentioned earlier, human capital stock is the series of average years of schooling taken from Barro and Lee (2010), while the variable of human capital per worker is constructed from the human capital stock data using the country specific rates of returns to education (already explained in the previous chapter). Series for the capital-labor ratio is calculated by first computing the yearly values for the total capital stock for each country over the period 1960-2008. The procedure for generating the capital stock series is the one followed by many studies including Barro and Lee (2010) and Hall and Jones (1999). Specifically, capital stock is generated by applying the perpetual inventory method on initial values of capital stock and total investment series as:

$$K_{i,t} = I_{it} + (1 - \delta)K_{i,t-1} \quad (6.5)$$

K_{it} and I_{it} denote the capital stock and the investment for country i in period t , and δ is the depreciation rate assumed to be constant for all countries and all periods. The initial capital stock is calculated by $K_{0,i} = I_{i0} / (g + \delta)$. In which, I_{i0} denotes investment of any country i in the year preceding to t or in year t . g is the average growth rate of real output in the previous five years including t , while a 6% value of δ is assumed [Barro and Lee (2010); Bernanke and Gurkaynak (2001)].⁸⁹

⁸⁹ These estimates are based on the assumption that growth rate of real output is equal to the growth rate of real investment in the long run. It is worth noting that estimations of conditional β -convergence in chapter 5 are based on a depreciation rate of 3%, which is consistent with the relevant literature on the subject.

Rather than proxy the unobservable TFP by either output per worker or fixed effects as in Dowrick and Rogers (2002) and Di Liberto et al. (2008) respectively, the TFP is computed for all the sample countries over the period 1960-2008. In this context, two commonly utilized approaches for estimating TFP are the growth accounting method and the stochastic production frontier approach. The former method is most commonly utilized in macroeconomic growth studies such as Baier et al. (2006); while, the latter approach estimates the TFP growth but not the TFP in level forms. Therefore, estimation of level form TFP in the following is based on the growth accounting method of Hall and Jones (1999). Though a majority of the studies have estimated the TFP growth, Hall and Jones (1999) estimated the TFP in the level form. Following Hall and Jones (1999), solving equation (6.1) for A generates the TFP in levels form. The value of α is assumed to be equal to 0.33 in many studies including Klenow and Rodriguez-Clare (1997), Hall and Jones (1999) and Baier et al. (2006). While, different studies estimate different values of η ; 0.1 by Judson (1996), 0.3 by Mankiw et al. (1992), less than one third by Bills and Klenow (2000) and 0.3 by Pritchett (2001). Given this literature, η is assumed to be equal to 0.3 in the following analysis.⁹⁰ Since, only five yearly data are available for human capital stock, TFP estimates also maintain the same (five-yearly) frequency.

Maintaining the identical sample utilized in the previous chapter, analysis on sources of convergence pertains to the world countries and its various geographic and income categories for the period 1960-2008. Utilizing these datasets, equation (6.3) is estimated using the panel data non-linear least squares method with cross-sectional and time fixed effects. While the panel data least squares dummy variable technique is used to estimate equation (6.4) of conditional convergence in TFP.

However, conclusions on conditional β -convergence, mainly, remain unchanged with a depreciation rate of 6%.

⁹⁰ It is worth emphasizing here that estimation of TFP convergence based on a different value of η results in a similar value of the convergence coefficient.

6.3.3. Results and Discussions

Results on the conditional convergence of physical capital per worker, human capital per worker, human capital stock, workers to population ratio and TFP are given in Table 6.3.⁹¹ These results are for the world sample of 98 countries. Besides the estimates of conditional convergence, results on time dummies are also reported in Table 6.3 to explain the overtime changes in growth rates of each of above mentioned variables. In comparison to the referenced period, 1960-65, the five yearly growth rates of human capital stock and human capital per worker have consistently increased for the world countries during the subsequent period, 1965-2008. However, the positive growth in human capital per worker is quite substantially less in size than that for the human capital stock. Similar is the trend in the workers to population ratio with its positive growth for all the years following 1970.

Contrary to the positive trend in convergence in the human capital variables and the workers to population ratio, TFP growth of world countries has a fluctuating trend over the sample period. There are no significant differences in TFP growth rates for the first two decades of this period. However, the huge negative TFP growth in 1980-85 can be explained through the oil price shocks of 1970s. The second significant change in TFP growth is observed during the first half of 1990s in which the five-year average TFP growth was much lower in comparison to its value in 1960-65. According to Crafts (2006, p. 2), '*Notwithstanding the advent of ICT for the industrial countries as a whole, there was no resurgence in TFP growth during the 1990s*'. Crafts (2006) further argued that not only was the TFP growth in industrial countries in 1990s was lower than its growth during the golden age (1950-73); the Asian and Latin American countries also

⁹¹Sources of conditional β -convergence were also estimated utilizing the methodology of Dowrick and Rogers (2002) but using the system GMM technique, because system GMM is a preferred estimation technique over the first-difference GMM. However, results were quite implausible with negative TFP conditional convergence for the European and Asian regions. While, conditional convergence in factor inputs was also negligible for the Asian and Latin American regions. Though, these two regions have reasonable evidence of conditional β -convergence in output per worker in the previous chapter.

had a slow growth in TFP while, Africa had a negative TFP growth for the decade of 1990s.⁹²

Table 6.3. Sources of Convergence: World Countries (1960-2008)

Number of observations/No. of countries=980/98					
Source/ Regressors	Physical capital per worker	Human capital stock	TFP	Workers to population ratio	Human capital per worker
$\ln(x_{it})/\ln\left(\frac{A_t^*}{A_{i,t}}\right)$	-0.177** (8.69)	-0.126** (7.32)	0.193** (9.96)	-0.11** (5.58)	-0.0028 (0.11)
Year 2 (1965-70)	0.04** (2.79)	0.017 (1.54)	0.049 (1.24)	0.0002 (0.12)	0.006** (3.33)
Year 3 (1970-75)	0.075** (4.34)	0.064** (4.01)	-0.066 (1.77)	0.025** (6.05)	0.014** (3.83)
Year 4 (1975-80)	0.089** (4.23)	0.086** (5.67)	-0.03 (0.60)	0.027** (6.78)	0.0205** (4.73)
Year 5 (1980-85)	0.007 (0.31)	0.116** (7.4)	-0.23** (5.23)	0.03** (7.58)	0.032** (6.98)
Year 6 (1985-90)	-0.026 (1.18)	0.102** (6.07)	-0.071 (1.62)	0.047** (10.34)	0.029** (5.61)
Year 7 (1990-95)	-0.005 (0.21)	0.106** (6.55)	-0.142** (3.01)	0.046** (8.18)	0.034** (5.91)
Year 8 (1995-00)	0.015 (0.61)	0.084** (5.07)	-0.076 (1.44)	0.054** (12.13)	0.02** (3.45)
Year 9 (2000-05)	0.029 (1.22)	0.095** (5.38)	0.027 (0.58)	0.053** (10.92)	0.022* (2.52)
Year 10 (2005-08)	0.06* (2.51)	0.094** (4.94)	0.018 (0.43)	0.049** (11.09)	0.02* (2.19)
Implied θ/ϕ	0.039** (7.88)	0.027** (6.84)	0.039** (9.96)	0.023** (5.26)	0.0005 (0.11)

All of the estimations for sources of convergence are based on equation (6.3), except for the TFP, which is based on equation (6.4). Conditional convergence rates are estimated using the five-yearly pane data of 98 world countries over the period 1960-2008. The dependent variable in each of the estimations is the five-yearly growth rate of each variable, while the considered regressor is its value at the start of the panel interval. Implied values of θ are computed using the Delta method. Estimated values of rate of TFP convergence, ϕ , are based on equation (6.4), while equation (6.3) is the basis for estimated values of θ . According to equation (6.3), a negative coefficient on $\ln(x_{it})$, reported in the first row, indicate convergence; but, it is opposite for equation (6.4), in which convergence requires the coefficient on $\ln\left(\frac{A_t^*}{A_{i,t}}\right)$ to be positive.

⁹² Though, some of the East Asian countries were having high economic growth rates in 1990s; yet, according to Crafts (2006), the contribution of TFP growth was relatively less than that of capital-labor ratio to these high economic growth rates.

The physical capital-labour ratio for the world countries also has a fluctuating trend over the study period. Compared to its figure in 1960-65, the growth values of the world capital-labour ratio are significantly higher over the period 1965-80. However, after this consistent positive growth, the average world capital-labour ratio may have illustrated a constant pattern because it was not significantly higher than its initial value of 1960-65. In the recent years i.e. 2005-08, the growth of the capital-labour ratio is positive and significant [see Table 6.3].

It is evident from Table 6.3 that the factor inputs, physical capital labour ratio and human capital stock, and TFP are conditionally converging. Thus, both the *classical convergence* of diminishing returns to capital per worker, extended by Solow-Swan model and *technological convergence* in terms of TFP catch-ups are equally contributing to the convergence of output per worker in the world countries. The annual rate of conditional convergence for human capital stock, 2.7%, which is obtained from the *implied θ/ϕ* row, is somewhat less than that for the capital-labour ratio and TFP, which are converging at an identical rate of 3.9%. In contrast, the series of human capital per worker has not shown any evidence of conditional convergence. These contrasting results for the conditional convergence of human capital stock and human capital per worker may be due to country specific differences in returns to education owing to their specific structural characteristics. Moreover, the data on returns to education is country specific but is not available for different time points used in the analysis. Therefore, a lack of a dynamic component in the data for returns to education may also explain the contrary results for conditional convergence of human capital stock and human capital per worker. The output per worker in equation (6.1) is a function of human capital per worker; therefore, analysis of sources of convergence should include human capital per worker. However, the additional results on the conditional convergence of human capital stock are reported for comparison. Besides the above mentioned sources of convergence, convergence results for the workers to population ratio may also explain the per capita income convergence. The annual rate of conditional convergence for the workers to population ratio is 2.3%. This may confirm and explain the higher rate of conditional

convergence for per capita income as compared to that of output per worker discussed in the previous chapter [see Table 5.3].

Earlier, Cohen (1996) confirmed unconditional β -convergence in human capital and physical capital for the world countries. Dowrick and Rogers (2002) have estimated a 3.4% rate of TFP convergence for 57 countries over the period 1965-90. The annual rate of combined convergence of human capital and physical capital per worker was equal to 4.8% for the sample. Despite different methodologies, the results of the study by Dowrick and Rogers (2002) are quite similar to the conditional convergence results reported in Table 6.3. Similarly, Aiyar and Feyrer (2002) have also estimated conditional TFP convergence at a rate of 3% utilizing the data of 86 countries for the period 1960-90. However, a much higher rate of conditional TFP convergence, 5.7%, was estimated by Miller and Upadhyay (2002) for 83 countries over the period 1960-1990. These authors have also confirmed absolute TFP convergence among the sample countries. In contrast, Di Liberto et al. (2011) find no absolute TFP convergence for the world sample over the period 1960-2003. Rather the world TFP convergence is conditional on human capital stock according to Di Liberto et al. (2011). The cross-sectional data based evidence on conditional TFP convergence, but conditional divergence in both human capital and physical capital for 77 world countries was reported by Wong (2007). However, that study only covered a period from 1960-85.

Results on the sources of convergence for various geographic and income categories are reported in Table 6.4. Maintaining the tradition of previous analysis of this study, the results include four geographic regions namely Asia, Africa, Europe and Latin America and the four income categories, high income, upper middle income, lower middle income and low income. Though, the conditional β -convergence analysis of output per worker and income in the previous chapter does not include the high income category because of small N (equal to 10) for the system GMM estimations; yet, results on the sources of convergence for this category can furnish interesting comparisons with those for other income clusters. Since, the focus of analysis is the sources of convergence, Table 6.4, therefore, only reports the estimated values of conditional

Table 6.4. Sources of Convergence: Geographic and Income Categorizations (1960-2008)								
Source/convergence rate	Africa	Asia	Europe	Latin America	High Income	Upper middle Income	Lower Middle Income	Low income
No. of observations/No. of countries	320/32	190/19	190/19	220/22	100/10	130/13	210/21	540/54
Total Factor Productivity (TFP)	0.048** (7.56)	0.031** (5.10)	0.065** (8.47)	0.037** (4.34)	0.021* (2.92)	0.067** (4.57)	0.042** (4.87)	0.037** (6.86)
Physical Capital-labour ratio (K/L)	0.046** (6.78)	0.033** (3.17)	0.071** (9.58)	0.036** (4.51)	0.016 (1.84)	0.066** (5.87)	0.051** (6.73)	0.036** (5.7)
Human capital-labour ratio (H/L)	-0.002 (0.57)	0.02* (2.43)	0.021 (1.07)	-0.004 (0.43)	0.07** (2.91)	0.02 (0.96)	0.025 (1.38)	0.00006 (0.01)
Human capital stock	0.042** (4.5)	0.041** (9.28)	0.037* (1.97)	0.017** (3.38)	0.035** (10.15)	0.09 (1.67)	0.052** (4.89)	0.04** (6.59)
Workers to population ratio (L/P)	0.0002 (0.02)	0.036** (3.69)	0.023 (1.39)	0.036** (3.15)	0.003 (0.19)	0.035** (3.54)	0.059** (4.85)	0.015** (2.84)
GDP per worker	2.5%	2.8%	4.2%	3.3%	-	2.6%	3.8%	1.6%
GDP per capita	1.8%	3.8%	4.6%	3.5%	-	3.2%	4.4%	1%
<p>These summarize the coefficients on convergence from a series of regressions on equations (6.3) and (6.4). Conditional convergence rates are estimated using the five-yearly panel data over the period 1960-2008. The dependent variable in each of the estimations is the five-yearly growth rate of each variable, while the considered regressor is its value at the start of the panel interval. The panel data non-linear least squares technique with cross-sectional and time fixed effects is utilized for estimating the conditional convergence of physical capital-labour ratio, human capital-labour ratio, human capital stock and the workers to population ratio. While, panel data least squares regression of equation (6.4) is used for estimating the conditional convergence in TFP.</p>								

convergence coefficients i.e. θ and ϕ from equations (6.3) and (6.4) respectively. Besides, the conditional convergence rates of GDP per worker and GDP per capita, estimated in the previous chapter, are also reported in Table 6.4 for comparisons.⁹³

Beginning the discussion with the TFP convergence among various geographic categories, the highest rate pertains to the European region with a value of 6.5%. It is worth mentioning here that the technological leader countries with highest TFP levels among the whole sample, as per equation (6.4), also belong to the European continent. The other three geographic categories e.g. Africa, Asia and Latin America have their TFP convergence rates equal to 4.8%, 3.1% and 3.7% respectively. The higher African TFP convergence may be explained by the fact that most of the African countries are the furthest from the technological leaders over the entire study period. The European continent also has the highest rate of conditional convergence in physical capital per worker, equaling 7.1%. The physical capital per worker in Africa is converging at a rate of 4.6%, while Asian and Latin American regions have approximately equal rates of convergence of physical capital per worker, 3.3% and 3.6% respectively.

Like the geographic regions, the highest rates of TFP and physical capital per worker convergence pertain to the upper middle income group which primarily includes the European countries. The rate of TFP convergence for this group is 6.7%, while it is 2.1%, 4.2% and 3.7% for the high income, lower middle income and low income clusters respectively. Correspondingly, respective conditional convergence coefficients of physical capital per worker are 1.6%, 6.6%, 5.1% and 3.6% for the high, upper middle, lower middle and low income groups. However, the said coefficient for the high income group is insignificant which is either caused by small sample size, $N=10$, or may validate the convergence postulation of NGM. According to this postulation, rich countries with higher physical capital per worker are nearer to the steady state and, thus, are converging at a lower rate. But the opposite is not true in this study, since, the low

⁹³ It is worth mentioning here that results on the convergence of physical capital-labour ratio and TFP convergence are sensitive to the specific value of depreciation rate used in the analysis. Because, such results based on a 3% rate of depreciation (utilized in estimation of conditional β -convergence in Chapter 5) are quite different than those in Table 6.4 (with 6% depreciation rate). However, convergence estimates with 6% depreciation rate appear more plausible.

income cluster is not characterized by the highest convergence rates in Table 6.4 which may indicate some specific structural, geographic and/or institutional problems in these countries, ensuing lower convergence. One of the common observations regarding the sources of convergence is that both the physical capital per worker and TFP are conditionally converging at approximately equal rates throughout the Table 6.4.

In contrast to the above, human capital per worker has not shown any evidence of conditional convergence for the majority of the samples i.e. Africa, Europe, Latin America, upper middle income, lower middle income and low income while, human capital stock is converging in these clusters at an annual rate of 4.2%, 3.7%, 1.7%, 1%, 5.2% and 4% respectively. As mentioned and explained before, the contrary convergence results for the human capital stock and human capital per worker also pertains to the world sample in Table 6.3. The only two clusters with significant evidence for the conditional convergence of human capital per worker are the Asian continent and the high income group. The annual convergence rate in the former is 2% and it is 7% for the latter, while the respective conditional convergence coefficients for the human capital stock are 4.1% and 3.5% for these groups. Higher average growth in human capital stock together with smaller differences in returns to education may have caused higher convergence in human capital per worker for the Asian countries.⁹⁴

There are very few studies on the sources of convergence of output per worker and/or on the TFP convergence for the above mentioned geographic and income clusters. Indeed, it is to note that there is no prior evidence on the conditional convergence of TFP and capital labour ratio for Asian and Latin American countries and in this respect the research makes an original contribution, as well as updating previous research on other regions and groupings. However, through declining values of coefficient of variation over the period 1970-96, Sab and Smith (2002) have also confirmed convergence in various indicators of human capital for the sub-Saharan

⁹⁴ The standard deviation of the coefficients on returns to education for Asian countries is equal to 2.9, while the average growth of human capital stock is 2.8% for the sample.

African (SSA) countries.⁹⁵ In a study on the sources of convergence for the SSA countries, Ahmed and Suardi (2007) have concluded rates of TFP convergence in the range of 1.2% to 1.8%. These rates are much lower than the reported rate of African TFP convergence in Table 6.4. The study by Ahmed and Suardi (2007) is based on the methodology of Dowrick and Rogers (2002) and covers a sample of 28 SSA countries for the period 1961-2000. However, the estimated rates of classical convergence (factor input convergence) in Ahmed and Suardi (2007), of 3.7% to 3.9%, are quite similar to those reported in Table 6.4 (4.6% for physical capital and 4.2% for the human capital stock).

In complete contrast to the results reported in Table 6.4, Di Liberto and Usai (2010) find no TFP convergence among the 199 European regions for the period 1985-2006. While, in an analysis of sources of the convergence for various income groups over the time span 1960-1989, Miller and Upadhyay (2002) have concluded the highest rate of TFP convergence, 6.1%, for the low income countries, while the reported rate for the middle income countries is 5.7%. However, there was no significant TFP convergence among the high income group in their study. The estimation of TFP convergence in Miller and Upadhyay (2002) was based on equation (6.3) but not equation (6.4), which is the basis of the analysis in this chapter.

In addition to the sources of convergence of GDP per worker discussed in the foregoing, convergence figures for the workers to population ratio (L/P) in Table 6.4 are also explaining the conditional β -convergence in GDP per capita. Among the geographic categories, L/P is significantly converging in Asia and Latin America but not in Africa and Europe. The annual rate of conditional convergence in L/P is 3.6%, each for Asian and Latin American regions. Therefore, in these two regions, per capita income convergence is higher than that of GDP per worker, which is also true for

⁹⁵ Authors have reported results for primary enrollment rate, secondary enrollment rate, tertiary enrollment rate, male primary enrollment rate, female primary enrollment rate, male secondary enrollment rate and female secondary enrollment rate.

Europe with its positive but insignificant convergence coefficient for L/P . Apart from the high income group, all other income clusters are also characterized with conditional convergence in L/P . Rates are 3.5%, 5.9% and 1.5% for the upper middle, lower middle and low income countries respectively.

Results of the African and Asian regions in Table 6.4 provide a useful comparison with their approximately equal rates of GDP per worker convergence (2.5% for Africa and 2.8% for Asia) together with quite different rates of income convergence (1.8% for Africa and 3.8% for Asia). The underlying cause for this being the trend in demographic age structure is also reflected in the convergence rates of L/P . It is already recognized that the demographic structure of the workforce has a significant impact on productivity and output [Feyrer (2007)]. Similarly, a positive difference between the growth rates of working population and total population, or the ‘*demographic gift*’ as termed by Bloom and Williamson (1998), has a positive impact on the TFP [Kogel (2005)]. The Asian and African regions are respectively characterized with the presence and absence of this *demographic gift* [see also Table 5.2]. Results on the convergence in Table 6.4 may indicate that this *demographic gift* or its reverse is also having both direct and indirect impacts on the income convergence of countries.

6.3.4. Conclusions

The sources of convergence of GDP per worker and GDP per capita have been analyzed for the world countries and for various geographic and income clusters. It is important to note that, in an effort to ascertain the relative contribution of convergence of each input into that of output per worker/per capita income, all these conditional convergence rates are estimated in separate regressions. However, the above analysis is not a convergence accounting exercise in which the individual convergence rates for each input are related in some mathematical identity to generate the corresponding convergence figure for the output per worker. Analyses confirm that physical capital per worker and TFP are

conditionally converging for all samples, while evidence for the human capital per worker convergence is not common.

Results on the sources of convergence are consistent with the previously estimated (also reported in Table 6.4) rates of conditional β -convergence of GDP per worker and income. For instance, Europe's highest rates of TFP and physical capital convergence are compatible with its highest rates of GDP per worker convergence. In contrast, lower rates of TFP and physical capital convergence are joined with high human capital per worker convergence to explain the convergence in output per worker in Asia. However, low income countries have very low convergence rates both for output per worker and income despite the fact that TFP, physical capital per worker and L/P are conditionally converging in these countries. This may be explained by the negligible rate of convergence in human capital per worker. More specifically, this low convergence may be caused by the poor institutional quality in low income countries as discussed in the previous part, 6.2.

6.4. DISTRIBUTION OF STEADY STATES

As already defined, the concept of conditional β -convergence involves the convergence of countries towards their respective steady state levels. Given the evidence of conditional β -convergence for the world countries and among various other regional and income groups, it is imperative to estimate the steady state levels of output per worker for each country. A study of distribution of these steady states can give useful insights for the long-run convergence behaviour of countries. Earlier, Jones (1997) has estimated the steady states of countries and analyzed their distribution in a cross-sectional framework using the data of 74 countries from 1960-90. But panel framework of conditional convergence entails varying steady states over time for any individual country. Therefore, five-yearly steady states are estimated for each country and their distributions are compared within the world sample and various regions.

According to equation (5.12) the steady state level of output per effective worker is:

$$y^* = \left[\frac{(s_h)^\eta (s_k)^\alpha}{(n + g + \delta)^{\alpha + \eta}} \right]^{1/(1 - \alpha - \eta)}$$

Alternatively it can be written as:

$$\ln y^* = \frac{\eta}{1 - \alpha - \eta} \ln s_h + \frac{\alpha}{1 - \alpha - \eta} \ln s_k - \frac{\alpha + \eta}{1 - \alpha - \eta} \ln(n + g + \delta) \quad (6.6)$$

Substitution of the value of s_h from equation (5.11) describes steady state output per effective worker as a function of steady state level of human capital, h^* :

$$\ln y^* = \frac{\eta}{1 - \alpha} \ln h^* + \frac{\alpha}{1 - \alpha} \ln s_k - \frac{\alpha}{1 - \alpha} \ln(n + g + \delta) \quad (6.7)$$

Since:

$$\ln y^* = \ln \left(\frac{\hat{y}^*}{A^*} \right) = \ln \hat{y}^* - \ln A^*$$

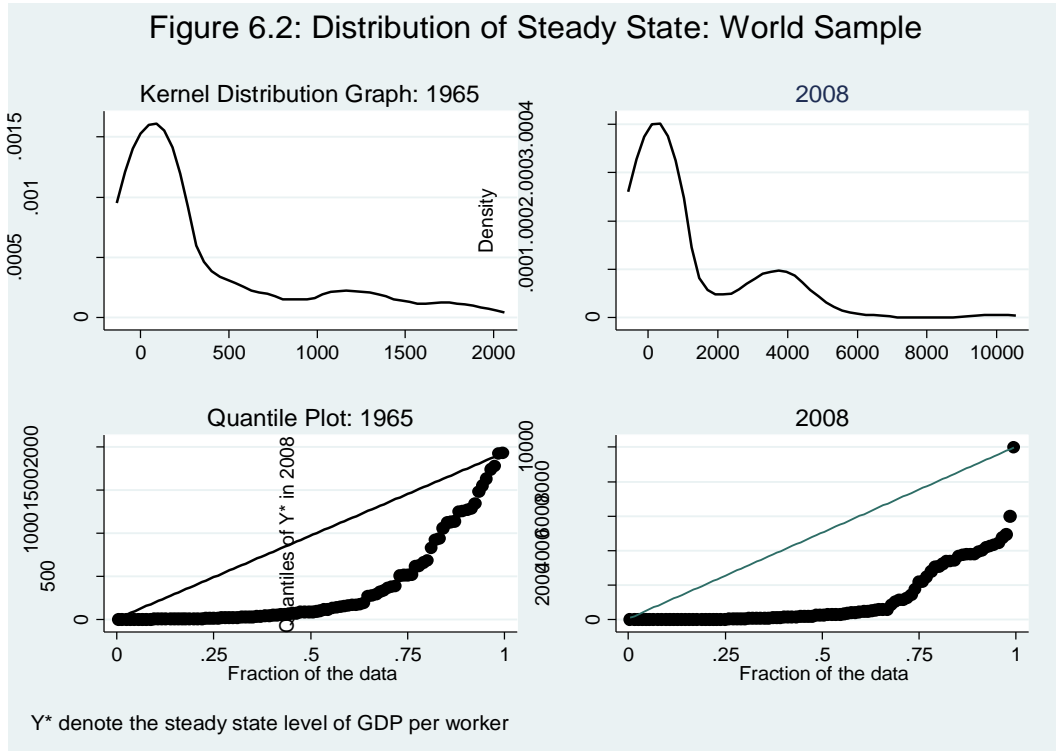
Substitution of the above in equation (6.7) gives:

$$\ln \hat{y}_t^* = \ln A_t^* + \frac{\eta}{1 - \alpha} \ln h_t^* + \frac{\alpha}{1 - \alpha} \ln s_k - \frac{\alpha}{1 - \alpha} \ln(n + g + \delta) \quad (6.8)$$

In the above equation, \hat{y}_t^* , h_t^* , A_t^* denote the steady state levels of output per worker, human capital per worker, and TFP respectively. Steady state values of output per worker are calculated with five yearly intervals utilizing already generated variables, namely, human capital per worker, TFP, physical capital accumulation s_k , and sum of workers growth, depreciation rate and technological growth $(n + g + \delta)$. As already mentioned, values of α and η are assumed to be equal to 0.33 and 0.3 respectively. Steady state values of human capital per worker and TFP are their values in the terminal

period of an interval, while, non-overlapping averages in a panel interval are considered for s_k and n .⁹⁶

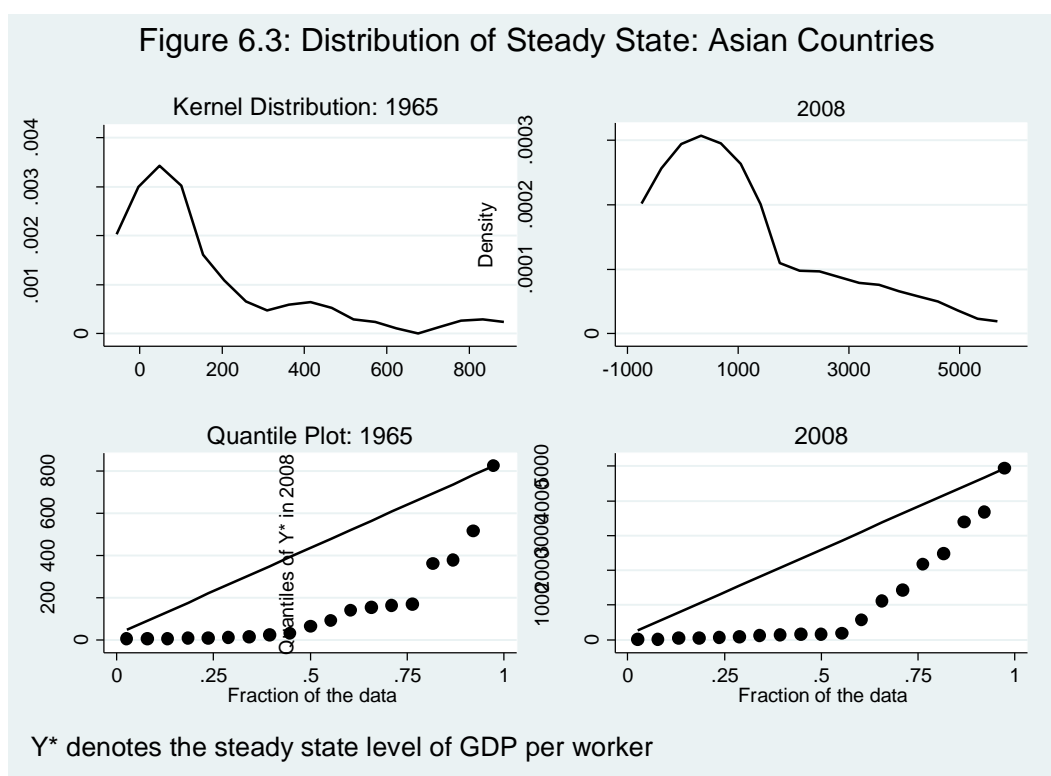
The distribution of steady states is shown using the *quantile plot* and the kernel distribution for the initial and terminal periods of the sample, i.e. 1965 and 2008. The initial and terminal periods are chosen to study and compare the patterns of steady states over the sample period of 50 years. The quantile graph ‘plots the ordered values of a variable against the quantiles’. The quantile plots and kernel distributions for the world sample are given in Figure 6.2. The kernel graph illustrates the polarization of the world countries through twin peaks in the world distribution of steady states of output per worker in 2008. Similarly, the quantile graph depicts a worsening of the distribution in 2008 compared to that in 1965. This is because, the number of countries in the highest quartile has reduced in 2008 and a gap has emerged between the country with the

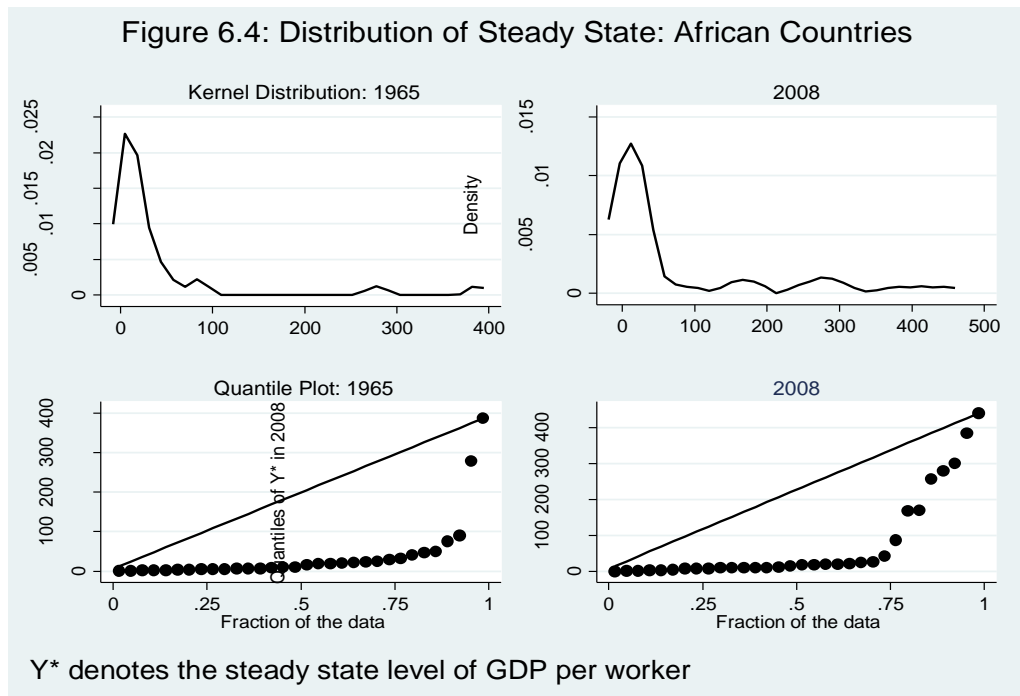


⁹⁶ Terminal values for human capital stock and five-year averages for s and n are taken for steady states. The panel data based conditional β -convergence equation, (5.20), utilizes the average values for s and n , while terminal value in a panel interval is used for the human capital variable.

highest output per worker and the remaining economies in the upper quartiles. Moreover, the fraction of countries in the lowest quartile has also increased. This tendency of higher values of output per worker for relatively rich countries and reduced values for some of the poor countries was also confirmed by Jones (1997).

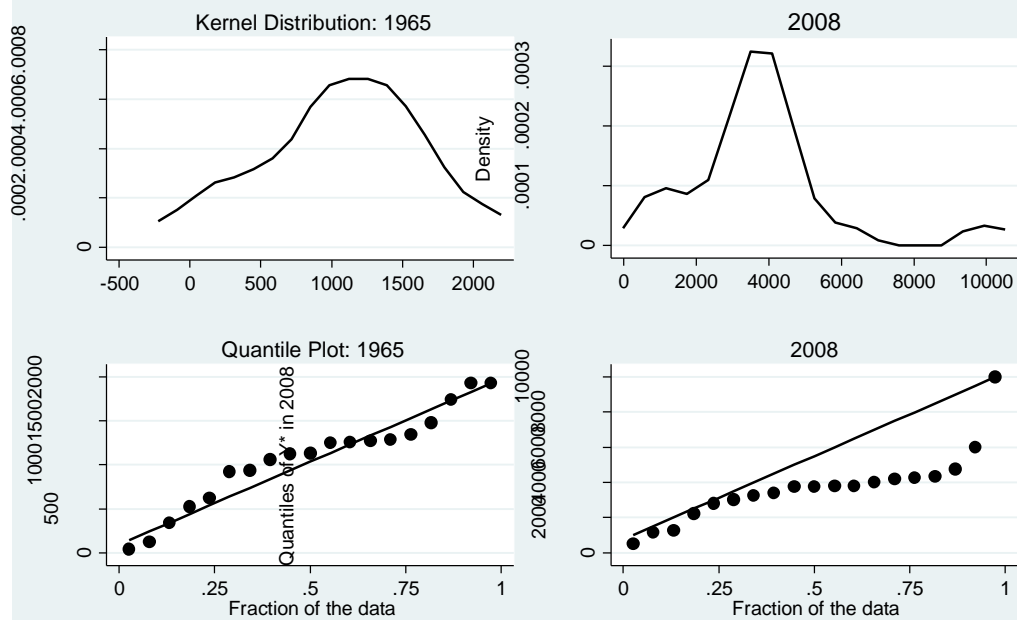
An important question at this point is whether various regions in the world are also illustrating similar patterns in their steady states and how much they differ from each other. In an answer to this, steady state distributions for various geographic regions are also shown. Figure 6.3 illustrates the behaviour of steady states for the Asian countries which are depicting a catching-up tendency. A slight twin peak observed in the kernel distribution in 1965 has disappeared in 2008. Moreover, the number of countries in the upper quartiles has increased in the quantile plot for 2008. Like the Asian countries, output per worker for some of the countries is increasing towards the highest level for the African countries, shown in Figure 6.4. However, 75% of the sample lies within the lowest quartile of the steady state and the remaining sample is scattered in the upper quartiles leading to two additional small peaks in the kernel distribution.





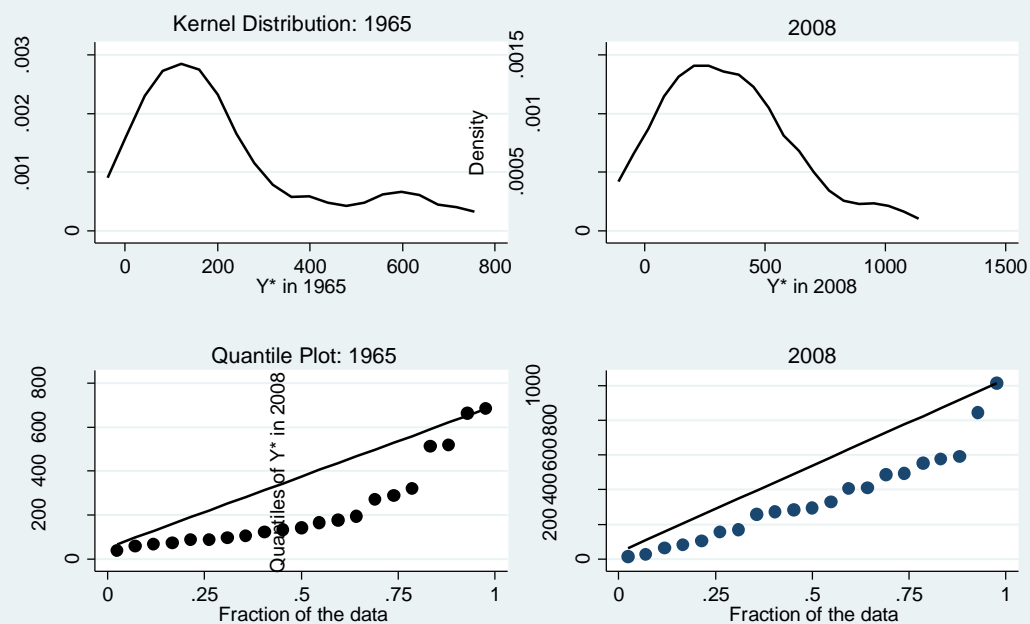
The approximate normally distributed steady states for the European countries in 1965 have taken a polarized transformation in 2008 [see Figure 6.5]. Countries in the sample were fairly equally distributed in each quartile in 1965 and were clustered around the *reference line*. But the respective pattern in the quantile graph is different in 2008, when the number of countries in the highest quartile has also fallen. In the quantile plot for the European sample for the year 2008, one obvious outlier is Luxembourg with the highest value of output per worker in the sample, which may have distorted the remaining distribution. This is also confirmed by redoing the graphs for Europe after excluding Luxembourg. The remaining sample has very similar steady state distribution in 2008 as the full sample in 1965 (to be brief, those graphs are not presented here). Similarly, the distribution of steady states for the Latin American sample also has changed over the sample period as shown in figure 6.6. The distribution in 1965 has twin peaks, which are still observed in the distribution for 2008 but at different points in the graph. Here again, one outlier in the Latin American sample in 2008 is a small Caribbean country, Trinidad & Tobago with its highest output per worker as shown in

Figure 6.5: Distribution of Steady State: European Countries



Y^* denotes the steady state level of GDP per worker

Figure 6.6: Distribution of Steady State: Latin American Countries

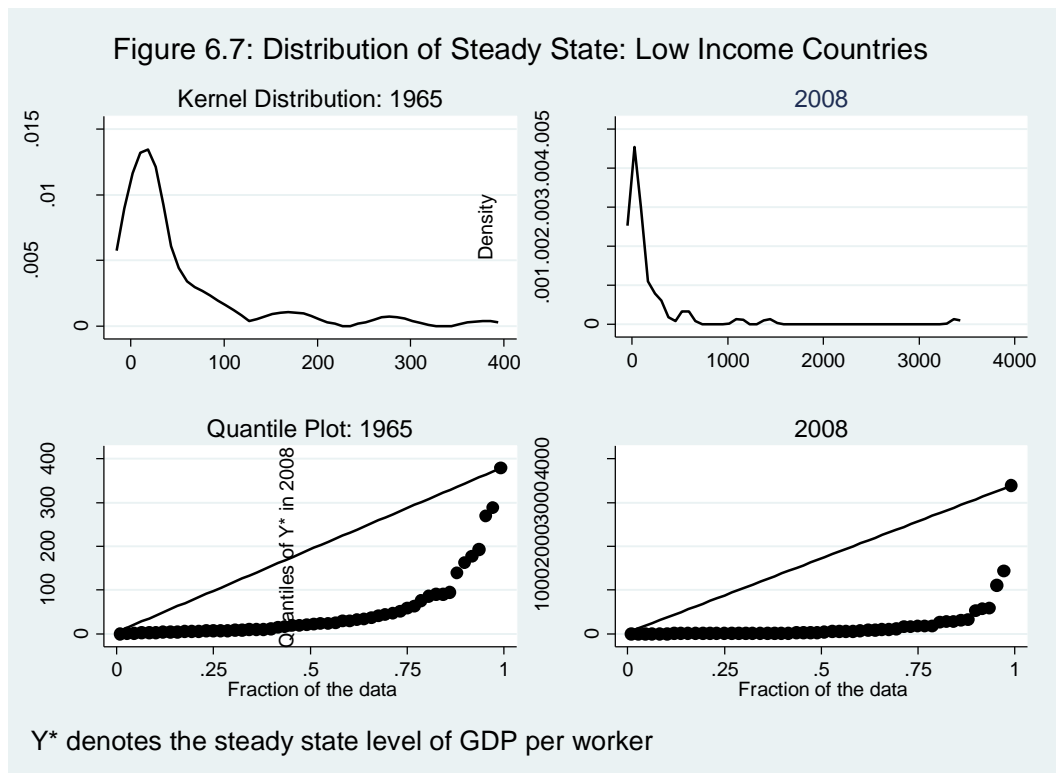


Y^* denotes the steady state level of GDP per worker

quantile plot. Excluding this country, the steady state distribution for the remaining sample has not changed substantially over the study period and also the kernel graph for the remaining sample is approximately symmetrical.

The steady states distribution within various geographic regions illustrates a mixed pattern for the period 1965 and 2008. Over the years, this distribution has improved for the Asian region but illustrates multiple peaks for the African countries. However, European and Latin American distributions have not changed over the sample period, if the single outliers in each of the samples are excluded. It may be inferred from the above that the changes in the steady state distribution for the world sample in 2008 are mainly sourced from the Asian and the African samples.

For a comparison, the steady state distribution for the largest income group namely the low income is illustrated in Figure 6.7. The kernel graph for the low income group in 1965 is positively skewed with multiple small peaks, while the distribution for 2008 is also characterized with small, indeed very small, peaks. Taiwan is the low



income country with the highest value of steady state output per worker in 2008 and more than 75% of the sample lies within first quartile. In other words, a large number of low income countries are not catching up towards the highest steady state level in the sample. It is worth mentioning here that the steady state distribution for the high and lower middle income groups have not changed in 2008 compared to the respective distribution in 1965. Nevertheless, the steady state distribution for comparatively small sample of upper middle income countries is a little different in 2008 than in 1965. Figures of steady state distribution for the high, upper middle and lower middle income groups are not displayed for the sake of brevity.

6.5. CONCLUSIONS

The convergence analysis in this chapter has focused on three different aspects, namely, the study of conditional β -convergence for low income countries with specific focus on initial human capital and the institutional quality index, sources of conditional β -convergence, and the distribution of steady states of GDP per worker of countries. In the first part, conditional β -convergence in four different clusters of low income countries, low initial human capital, high initial human capital, poor institutional quality and better institutional quality, is estimated using the augmented Solow model. This is the first empirical study on the comparative roles of initial human capital and/or institutional quality in the income convergence of poor countries. The results indicate conditional β -convergence among those low income countries, which have a better institutional quality but not those which have the higher initial human capital. This suggests a greater role for institutional quality than initial human capital in income growth and convergence of poor countries.

The 2nd part of this chapter analyzes the sources of conditional β -convergence of GDP per worker and GDP per capita within the context of the augmented Solow model. The rates of conditional β -convergence in the physical capital to labor ratio, human capital per worker/human capital stock and total factor productivity (TFP) are separately estimated for the world sample and for its geographic and income categories. In

addition, conditional β -convergence in the workers to population ratio is estimated to explain the difference between the convergence rates in GDP per worker and GDP per capita. Estimates on rates of conditional β -convergence for various sources are consistent with those of GDP per worker analyzed in the previous chapter. Similarly, significant conditional β -convergence in the workers to population ratio confirms a higher rate of convergence in GDP per capita relative to that of GDP per worker for a majority of samples. While, no significant conditional convergence in the workers to population ratio for the African continent, reflects both a constant pattern in dependency ratios and a higher rate of conditional β -convergence of GDP per worker relative to GDP per capita.

Since, conditional β -convergence involves convergence towards the respective steady state levels of output per worker, the study of the distribution of steady states can be regarded as an important component of its analysis. The augmented Solow model based steady state level of GDP per worker is estimated for the panel data, and distribution of steady states within various categories is compared for initial and terminal years. Results for the world sample indicated a twin peak in the distribution of output per worker in the year 2008, while an improved distribution for Asia, Europe and Latin America & Caribbean is observed. Moreover, there are small peaks in the distribution for African and low income countries, while no significant changes are observed in the distribution of steady states over the period 1960-2008 for upper middle and lower middle income countries.

Table A-1. Classifications of Low Income Countries and Income Growth Rates							
Initial Low Human capital countries		Initial High human capital countries		Countries with poor institutional quality		Countries with better institutional quality	
Algeria	0.9	Botswana	6.3	Algeria	0.9	Botswana	6.3
Bangladesh	1.1	Brazil	2.4	Bangladesh	1.1	Cameroon	0.8
Benin	0.6	China	4.5	Benin	0.6	China Version 2	4.5
Burundi	0.7	Dominican Republic	3.0	Brazil	2.4	Cote d'Ivoire	0.6
Cameroon	0.8	El Salvador	1.4	Burundi	0.7	Egypt	3.3
Central African Republic	-1.1	Fiji	1.7	Central African Republic	-1.1	El Salvador	1.4
Congo, Dem.	-3.2	Honduras	1.1	Congo, Dem.	-3.2	Fiji	1.7
Congo, Republic	1.9	Jamaica	1.0	Congo, Republic	1.9	Gambia, The	0.8
Cote d'Ivoire	0.6	Jordan	1.1	Dominican Republic	3.0	Haiti	-0.6
Egypt	3.3	Kenya	0.3	Ghana	1.5	Honduras	1.1
Gambia	0.8	Korea, Republic	5.7	Malawi	1.2	India	3.1
Ghana	1.5	Lesotho	2.5	Mali	1.2	Indonesia	3.6
Haiti	-0.6	Malaysia	4.5	Nepal	1.2	Jamaica	1.0
India	3.1	Mauritania	2.1	Nicaragua	-0.3	Jordan	1.1
Indonesia	3.6	Nicaragua	-0.3	Niger	-0.3	Kenya	0.3
Malawi	1.2	Paraguay	1.6	Pakistan	2.4	Korea, Republic	5.7
Mali	1.2	Philippines	1.7	Romania	4.1	Lesotho	2.5
Morocco	3.3	Romania	4.1	Rwanda	0.3	Malaysia	4.5
Mozambique	1.5	Senegal	0.1	Senegal	0.1	Mauritania	2.1
Nepal	1.2	Sri Lanka	3.5	Sierra Leone	0.6	Morocco	3.3
Niger	-0.3	Taiwan	6.0	Sri Lanka	3.5	Mozambique	1.5
Pakistan	2.4	Tanzania	1.8	Tanzania	1.8	Papua New Guinea	2.4
Papua New Guinea	2.4	Thailand	4.5	Togo	-0.1	Paraguay	1.6
Rwanda	0.3	Turkey	2.5	Turkey	2.5	Philippines	1.7
Sierra Leone	0.6	Zambia	0.1	Uganda	1.1	Taiwan	6.0
Togo	-0.1	Zimbabwe	-1.5	Zambia	0.1	Thailand	4.5
Tunisia	3.0			Zimbabwe	-1.5	Tunisia	3.0
Uganda	1.1						
Notes: Low income countries are separately divided on the basis of initial human capital stock and average institutional quality index. A list of countries within each of these four clusters, namely, initial low human capital, initial high human capital, poor institutional quality and better institutional quality, is presented in the table together with average annual income growth rate of each country over the period 1960-2008.							

Chapter 7

ANALYSIS OF CONDITIONAL σ -CONVERGENCE AND CONVERGENCE CLUBS

7.1. INTRODUCTION

The analysis in chapter 5 indicated considerable evidence on conditional β -convergence for the world sample and within its various geographic and income categories. The analysis was based on both the augmented Solow model and Barro's style income growth regressions. Generally, the rate of convergence for a sub-group is higher than that for the world sample except for the low income cluster. This cluster has the lowest rate of conditional convergence. The institutional quality has a significant role in the higher rates of conditional β -convergence for a sub-group of low income countries [see chapter 6]. Moreover, both convergence in factor inputs and convergence in TFP are contributing towards income convergence. As already mentioned, conditional convergence analysis entails convergence towards the steady states and the recent steady state distribution of output per worker for the world sample is characterized by twin peaks.

However, two of the critical assumptions underlying conditional β -convergence analysis are constant rate of technological growth across countries and constant speed of convergence, β , across countries and over time. These assumptions are relaxed by Phillips and Sul (2007a) who have developed a new methodology for the analysis of convergence. This notion of convergence is known as *growth convergence* or *conditional σ -convergence* by Phillips and Sul. The evidence of no convergence within a sample is further analyzed allowing for the possibility of convergence clubs. Discussing the convergence methodology by Phillips and Sul, Durlauf et al. (2009) maintained that

“this approach represents a key first step in integrating the transitory and steady state perspectives”. Some of the applications of this methodology on income convergence are extended by Phillips and Sul (2007b) and some other following studies like Panopoulou and Pantelidis (2009), Apergis et al. (2010), Fritsche and Kuzin (2011) and Bartkowska and Riedl (2012).

The heterogeneous behaviour of technological growth and the speed of convergence across countries and over time is rendered as the important characteristic of the methodology extended by Phillips and Sul (2007a). Another characteristic of the growth convergence approach developed by Phillips and Sul (2007a) is that it takes into account the possibility of transitional divergence of a country along with growth convergence in the long run. In other words, all countries may not be catching-up throughout the sample period; there may be some phases of transitional divergence in the long-run growth path of a country.

This chapter analyses the growth convergence and convergence clubs for the world sample and for its geographic and income clusters utilizing the approach given by Phillips and Sul. It is worth noting that the growth convergence for 88 countries of the world sample has already been analyzed by Phillips and Sul (2007a & 2009). This is studied again here because not only is the world sample different in this chapter (comprising 98 countries over the time span 1960-2009) but also the purpose of the analysis is to compare these results with those in previous chapters. However, the primary contribution of this chapter is the application of this methodology to different samples including Asia, Africa and Latin America & Caribbean and to four income clusters.

7.2. METHODOLOGY

This part explains the methodology underlying the test for growth convergence and convergence clubs by Phillips and Sul. Similar to other approaches of income convergence (absolute β -convergence and conditional β -convergence) analyzed earlier,

this is based also on the neoclassical growth model (NGM). Reconsidering the NGM in its general form:

$$Y = F(K, LHA)$$

As defined earlier, Y is the output, K is the physical capital and L , H and A denote the labour, human capital and technology respectively. With the Cobb-Douglas formulation of the NGM, the usual equation characterizing the transition path of a country is written in Phillips and Sul (2007a) as:

$$\log y_{it} = \log \tilde{y}_i^* + [\log \tilde{y}_{i0} - \log \tilde{y}_i^*] e^{-\beta_{it} t} + \log A_{i0} + g_{it} t \quad (7.1)$$

This equation is quite similar to equation (4.28) in Chapter 4. In equation (7.1), y_i is the real per capita income, while the steady state and the initial value of real effective per capita income are denoted by \tilde{y}_i^* and \tilde{y}_{i0} respectively. As previously described, A_{i0} is the initial level of technology, g denotes the technological growth rate, and β is the speed of convergence. The speed of convergence and technological growth are allowed to vary across countries i and over time t in equation (7.1), which is the basis for the analysis on convergence. It is worth noting that these two coefficients, β and g , were assumed to be homogenous across countries in the analysis on conditional β convergence in Chapter 5. However, in the words of Phillips and Sul (2005, p. 7), “Depending on the speed of learning in the countries and the time form of their exposure to the common technology, the actual technological progress of developing countries is likely to differ across i over time”.

Equation (7.1) is re-written by Phillips and Sul (2007a) as:

$$\log y_{it} = a_{it} + g_{it} t \quad (7.2)$$

This implies that $a_{it} = \log \tilde{y}_i^* + [\log \tilde{y}_{i0} - \log \tilde{y}_i^*] e^{-\beta_{it} t} + \log A_{i0}$. According to Phillips and Sul as $t \rightarrow \infty$, the term $e^{-\beta_{it} t}$ vanishes ($\rightarrow 0$) given that:

$$\beta_{it} t \rightarrow \infty \quad (7.3)$$

Therefore, given equation (7.1), it can be inferred that:

$$\text{as } t \rightarrow \infty, a_{it} \rightarrow \log \tilde{y}_i^* + \log A_{i0} \quad (7.4)$$

In this case, the long run growth path of $\log y_{it}$ in equation (7.1) is mainly determined by g_{it} .

In the procedure for deriving the methodology of growth convergence, further manipulation of equation (7.2) is based on the assumption that the growth path, (g_{it}) has a common component across different countries, denoted by μ_t . Phillips and Sul (2009, p. 1158) describe it as “*all economies share to a greater or lesser extent in certain elements that promote growth, for instance, the industrial and scientific revolution*”. Hence, equation (7.2) can further be written in the following form:

$$\log y_{it} = \left(\frac{a_{it} + g_{it}t}{\mu_t} \right) \mu_t = \delta_{it} \mu_t \quad (7.5)$$

Phillips and Sul (2009, p. 1158) wrote, “ δ_{it} measures the share of the common trend μ_t that economy i experiences. In general, the coefficient δ_{it} measures the transition path of an economy to the common steady state growth path determined by μ_t ”. Econometrically speaking, equation (7.5) represents a time-varying common factor model and δ_{it} can be referred as the *time varying factor loading coefficient* [Phillips and Sul (2007a)]. The semi-parametric form equation for δ_{it} is written as:

$$\delta_{it} = \delta_i + \sigma_i \xi_{it} L(t)^{-1} t^{-\alpha} = \delta_i + \psi_{it} L(t)^{-1} t^{-\alpha} \quad (7.6)$$

Phillips and Sul (2007a) consider δ_i as fixed and ξ_{it} as iid (0, 1) and dependent on t , while $L(t)$ is a *slowly varying function of time* characterized with $L(t) \rightarrow \infty$ as $t \rightarrow \infty$.

Phillips and Sul (2007a and 2009) base the methodology of growth convergence on an earlier definition of convergence given by Bernard and Durlauf (1996):

$$\lim_{k \rightarrow \infty} (\log y_{it+k} - \log y_{jt+k}) = 0 \quad (7.7)$$

Or alternatively:

$$\lim_{k \rightarrow \infty} \left(\frac{y_{it+k}}{y_{jt+k}} \right) = 1 \quad (7.8)$$

Equations (7.7) and (7.8) indicate that growth convergence entails similar levels of real per capita income across countries in the long run. Phillips and Sul (2007a) assert that equations (7.7) and (7.8) cannot be true under heterogeneous technology, unless the following holds:

$$g_{it+k} \rightarrow g, \text{ for all } i \text{ as } k \rightarrow \infty \quad (7.9)$$

Equation (7.9) implies that various cross-country rates of technological growth, (g_i) converge to a common long run growth rate. This is a necessary condition for growth convergence because, as mentioned earlier, the long run growth path of $\log y_{it}$ is mainly a function of g_{it} . Applying the definition of growth convergence in equation (7.8) on

$$\log y_{it} = \delta_{it} \mu_t$$

The convergence requires:

$$\lim_{k \rightarrow \infty} \delta_{it} = \delta \quad (7.10)$$

Given the equation (7.6), as $t \rightarrow \infty$ it follows that $\delta_{it} \rightarrow \delta_i$ (a fixed value) if $\alpha \geq 0$. For that reason, the test of the hypothesis of convergence also involves a null hypothesis of α being positive. The methodology for this convergence test given by Phillips and Sul (2007a) is described as follows.

Given the data of real GDP per capita for various countries $i = 1, 2, 3, \dots, N$ over the period $t = 1, 2, 3, \dots, T$ and equation (7.5) with unknowns μ_t and δ_{it} , δ_{it} cannot be

directly estimated. However, considering that μ_t is a common trend across all economies, it can be removed by defining a *relative transition coefficient* of the form:

$$h_{it} = \frac{\log y_{it}}{\frac{1}{N} \sum_{i=1}^N \log y_{it}} = \frac{\delta_{it}}{\frac{1}{N} \sum_{i=1}^N \delta_{it}} \quad (7.11)$$

It is obvious from equation (7.11) that the cross-sectional average of h_{it} is equal to one. Following the definition of growth convergence if $\delta_{it} \rightarrow \delta$ in the long run then $h_{it} \rightarrow 1$; consequently, the variance of h_{it} approaches zero. This can be written as:

$$\sigma_t^2 = \frac{1}{N} \sum_{i=1}^N (h_{it} - 1)^2 \rightarrow 0 \text{ when } t \rightarrow \infty \quad (7.12)$$

Phillips and Sul (2007a and 2009) calculate the relative transition parameters in equation (7.11) using the trend estimate of the real per capita GDP. This is applied by filtering the data, removing the business cycle component, because of the focus being the long run. Thereafter, the trend estimate of δ_{it} is denoted by $\hat{\theta}_{it}$ and the relative transition parameter is written as:

$$\hat{h}_{it} = \frac{\hat{\theta}_{it}}{\frac{1}{N} \sum_{i=1}^N \hat{\theta}_{it}} \quad (7.13)$$

Given this background a regression test is developed for the analysis of growth convergence. This test is also known as the *regression t test* or the *log t regression*.

As mentioned earlier, the null hypothesis of growth convergence can be written as:

$$H_0 : \delta_i = \delta \text{ or } \alpha \geq 0 \text{ against the alternative } H_1 : \delta_i \neq \delta \text{ or } \alpha < 0$$

The cross-sectional variance for the transition parameter is:

$$H_t = \frac{1}{N} \sum_{i=1}^N (\hat{h}_{it} - 1)^2 \quad (7.14)$$

Based on equation (7.6), the corresponding regression equation for (7.14) is written as⁹⁷:

$$\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{a} + \hat{b} \log t + \hat{u}_t \quad (7.15)$$

For $t = [Tr], [Tr] + 1, \dots, T$ and r being a positive fraction. In the words of Phillips and Sul (2007a, p. 1790):

“discarding some small fraction r of the time series data helps to focus attention in the test on what happens as the sample size gets larger. The limit distribution and power properties of the test depend on the value of r . Our simulation experience indicates that $r = 0.3$ is a satisfactory choice in terms of both size and power”.

In equation (7.15), $L(t) = \log(t+1)$ and $\hat{a} = \log H_1 - 2\log\left(\frac{\nu_{\psi N}}{\delta}\right)$, where

$$\nu_{\psi N} = \sqrt{N^{-1}(1 - N^{-1}) \sum_{i=1}^N \hat{\sigma}_i^2}; \text{ while, } \hat{b} = 2\hat{\alpha} \text{ (in which the estimated value of } \alpha, \text{ given in}$$

the null hypothesis, is denoted by $\hat{\alpha}$). It is obvious that this estimation procedure does not make use of the full set of time-series observations, but simply a sub-set of it defined as $[Tr]$. Phillips and Sul (2007a, p. 1789) discuss equation (7.15) as follows:

“Under convergence, $\log\left(\frac{H_1}{H_t}\right)$ diverges to ∞ , either as $2\log L(t)$ when $\alpha = 0$ or as $2\alpha \log t$ when $\alpha > 0$. Thus, when the null hypothesis H_0 applies, the dependent variable diverges whether $\alpha = 0$ or $\alpha > 0$. Divergence of $\log\left(\frac{H_1}{H_t}\right)$ corresponds to $H_t \rightarrow 0$ as $t \rightarrow \infty$. Thus, H_0 is conveniently tested in terms of

⁹⁷ For a detailed derivation of this equation, see Appendix B.1. in Phillips and Sul (2007a).

the weak inequality null $\alpha \geq 0$. Since α is a scalar, this null can be tested using a simple one-sided t test”.

Equation (7.15) is termed as *logt regression equation*. Since the regression test incorporates the ratio of cross-sectional variance, Phillips and Sul (2007a) refer to this convergence test as *conditional σ -convergence* test.

Any evidence of no growth convergence across the full sample is investigated by allowing for the possibility of sub-groups of convergence within this full sample. This type of convergence is also known as club convergence [Phillips and Sul (2007a)]. Because Phillips and Sul (2007a, p. 1798) assert that, “*rejection of the null of convergence does not imply there is no evidence of convergence in the subgroups of panel. Many possibilities exist as we move away from a strict null of full panel convergence*”. A clustering algorithm based on the repeated *logt* regressions is utilized to determine the convergence clubs.

Initially, a core group of countries, denoted by G_k , includes at least K members with some tendency of convergence. For this purpose, the first k (sub group) highest cross-sectional units in the panel are chosen once these cross-sectional units have been ordered in accordance with the last observation. The *logt* regression is estimated and the test statistics t_k is calculated for this subgroup G_k . The size of the core group k^* is determined by maximizing t_k according to the criterion:

$$k^* = \arg \max_k \{t_k\} \quad \text{subject to} \quad \min \{t_k\} > -1.65 \quad (7.16)$$

In equation (7.16), the t -value of 1.65 corresponds to 5% significance in a one-sided t -test with a degree of freedom equal to (or greater than) 30. Subsequently, in this process of group formation, one cross-sectional unit at a time is added to this core group for the possible membership and *logt* regressions are estimated each time. A cross-sectional unit is included in the group if the estimated t statistic in the *logt* regression is greater than some *chosen critical value*. This procedure is repeated for all cross-sectional units until the first convergence club emerges. All non-members of G_k form another club/sub-

group and again the $\log t$ test is conducted to determine whether or not these cross-sectional units form a convergence club. If not, the procedure is repeated a third time for all those cross-sectional units which are neither part of the first nor the second club. If there are no remaining cross-sectional units for which $t_k > -1.65$, then these cross-sectional units are considered to be diverging.

7.3. STUDY SAMPLE AND ESTIMATION

Since the analysis of growth convergence and convergence clubs requires data only on real GDP per capita, the study sample includes 110 countries over the time span 1960-2009. The data of real GDP per capita at purchasing power parity, measured as international dollars (I\$), is sourced from PWT-7. Growth convergence and convergence clubs are analyzed for the world sample and for four of its geographic regions, namely Africa, Asia, Europe and Latin American & Caribbean. Besides, this convergence analysis also covers four income categories of world countries consisting of high, upper middle, lower middle and low income countries. It is worth noting that the sample of world countries analyzed in the following is approximately similar to the one utilized in chapter 5 on the analysis of conditional β -convergence. That sample is restricted to 98 countries and spans over the 1960-2008 period; because of the availability of data for human capital stock. Moreover, all the oil countries which were excluded in the analysis on conditional β -convergence are not included.

Estimations for the overall growth convergence and convergence clubs are done by using the respective programme codes for $\log t$ regression and cluster algorithm, developed by Phillips and Sul.⁹⁸ In addition to these results, trend graphs for the minimum, maximum and median values of real GDP per capita for each sample is presented below. Moreover, trends in relative transition parameters for full sample and convergence clubs are important part of the results. Calculations of the relative transition parameters are based on equation (7.11) and the cross-sectional variance is computed by

⁹⁸ Gauss 9.0 is utilized for all these estimations.

using equation (7.12). All the regression results and graphs on growth convergence and convergence clubs are presented and discussed in the following part.

7.4. RESULTS AND DISCUSSIONS

7.4.1. World Sample

The result on the $\log t$ test of the growth convergence for the aggregate sample of 110 world countries is reported in first row of Table 7.1. The large negative value of t-statistics (-54.4) indicates that the null hypothesis of growth convergence is rejected. Hence, there is no evidence of conditional σ -convergence among the world countries. The steadily rising trend in the cross-sectional variance of the relative transition parameter of the world sample in Panel B of Figure 7.1 endorses this result. It is worth noting that the variance has declined during the last decade, i.e. 2000-2009, despite an increasing tendency throughout the period, 1960-1999. In this context, useful information on cross- sectional dispersion is provided by the trend in the median,

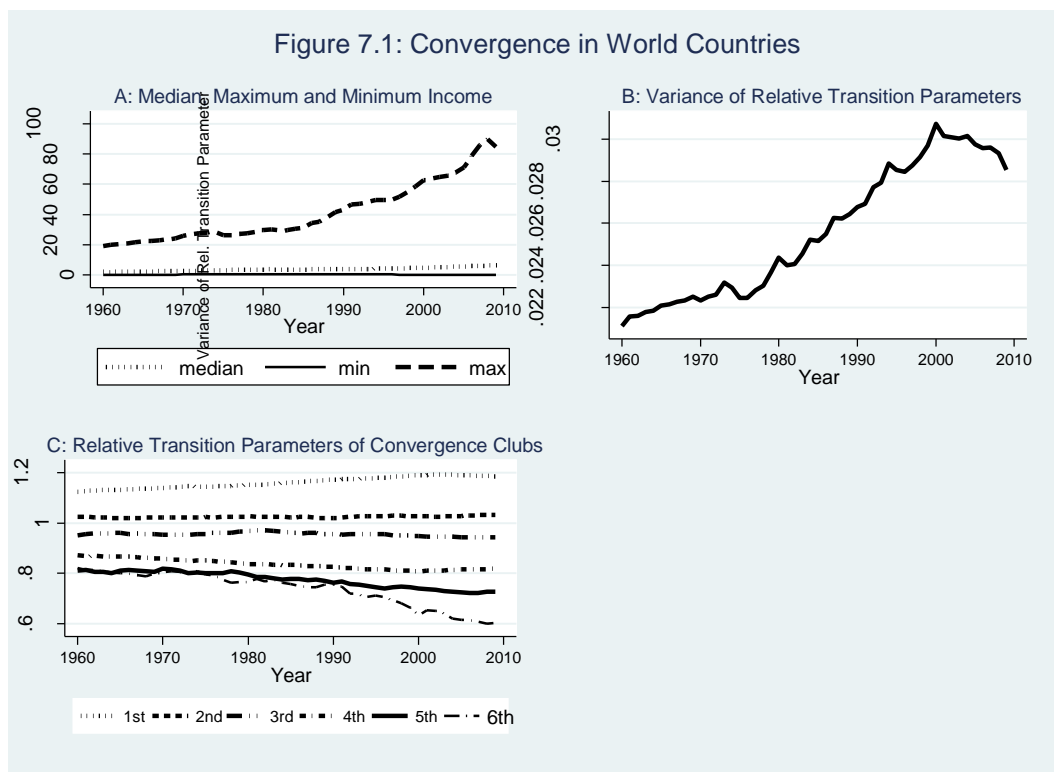


Table 7.1. Growth Convergence and Convergence Clubs for the World Sample 110 countries (1960-2009)		
Full sample log t test results		-0.871** (-54.4)
Convergence Clubs: Countries in club		Test results
1st Club (38): Australia, Austria, Barbados, Belgium, Botswana, Canada, China, Cyprus, Denmark, Equatorial Guinea, Finland, France, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, Korea Republic, Luxemburg, Malaysia, Mauritius, Netherlands, New Zealand, Norway, Portugal, Puerto Rico, Seychelles, Singapore, Spain, Sweden, Switzerland, Taiwan, Thailand, Trinidad & Tobago, UK and USA.		0.403 (8.93)
2nd Club(25): Algeria, Argentina, Brazil, Cape Verde, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, India, Indonesia, Jamaica, Mexico, Panama, Peru, Romania, South Africa, Sri Lanka, Tunisia, Turkey, Uruguay and Venezuela		0.309 (3.68)
3rd Club (12): Bolivia, Congo Republic, Fiji, Honduras, Jordan, Morocco, Namibia, Pakistan, Papua New Guinea, Paraguay, Philippines and Syria		0.032 (1.45)
4th Club (29): Bangladesh, Benin, Burkina Faso, Cameroon, Chad, Comoros, Cote d'Ivoire, Ethiopia, Gambia, Ghana, Guinea, Guinea Bissau, Haiti, Kenya, Lesotho, Madagascar, Mali, Mauritania, Mozambique, Nepal, Nicaragua, Nigeria, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda and Zambia		0.059 (0.92)
5th Club (4): Burundi, Central African Republic, Malawi, Niger		0.694 (12.37)
6th Club (2): Congo Democratic, Zimbabwe		1.908 (2.43)
<p>Notes: ** indicates significance at 1% level. The full sample results of $\log t$ test are based on equation (7.15) i.e. $\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{a} + \hat{b}\log t + \hat{u}_t$. The estimated coefficient corresponds to \hat{b} this equation and (.) denotes t-statistics. While, reported test results beside each club are the outcome of $\log t$ test for each club. The acceptance of null in each case confirms convergence within each club, which requires $t > -1.65$.</p>		

minimum and maximum values of real per capita GDP of the world countries in panel A of Figure 7.1. The minimum level of per capita income stayed constant over the 50 year period, while the median income has steadily increased. In contrast, the maximum level of per capita income has continuously increased except for the last one or two years, which may illustrate the impact of financial crisis of 2008. It is worth mentioning that the apparent equality of median and minimum levels of real per capita GDP in Panel A of Figure 7.1 is not a reality but is the result of very high maximum values of per capita income within the sample. Actually, the median real per capita income has approximately tripled in 50 years (i.e. from a value of I\$2,074 in 1960 to I\$6,293 in 2009).

Without any evidence of growth convergence in the overall sample, the possibility of convergence clubs is tested and, according to results, there are 6 convergence clubs within the sample of world countries, details of which are given in Table 7.1. The first club of relatively high income countries consists of 38 members from across the continents of Asia, Africa, Europe and Latin America & the Caribbean together with Australia, Canada, New Zealand, and USA. A majority of the countries in the 1st club belong to the European continent (18 countries), while 4 of them are African countries namely, Botswana, Equatorial Guinea, Mauritius and Seychelles. Three members of the 1st club, Barbados, Puerto Rico and Trinidad & Tobago are from the Caribbean region, all these having a relatively small population size compared to the other countries in the club. Further, 9 (East) Asian countries including the East Asian tigers are also part of the 1st convergence club. The relative transition parameters (of the

form in equation (7.11), defined as
$$h_{it} = \frac{\log y_{it}}{\frac{1}{N} \sum_{i=1}^N \log y_{it}},$$
 (y_{it} is per capita income) for the 6

clubs of world countries are illustrated in Figure 7.2. Trends in relative transition parameters are endorsing the finding of convergence clubs among specific group of countries reported in Table 7.1.

A further piece of information concerning these clubs is given in Table 7.2, showing average income growth rates of all sample countries, along with the value of

Table 7.2. Average Income Growth Rates for World Countries (1960-2009)

Country	Avg. Growth (%)	Real Income in 2009(I\$)	Country	Avg. Growth (%)	Real Income in 2009 (I\$)	Country	Avg. Growth (%)	Real Income in 2009 (I\$)
Luxembourg	3.3	84,525	Costa Rica	1.7	11,217	Congo, R.	2.1	2220
Norway	2.9	49,945	Uruguay	1.7	11,069	Nicaragua	-0.3	2192
Singapore	5.0	47,373	Panama	3.2	10,198	Nigeria	0.6	2034
Australia	2.4	41,304	Dominican Republic	3.0	9911	Cameroon	0.8	1811
United States	2.0	41,099	Turkey	2.3	9909	Zambia	0.0	1765
Switzerland	1.5	39,621	Romania	3.9	9737	Mauritania	2.0	1574
Austria	2.6	37,402	Mauritius	3.0	9484	Senegal	0.1	1492
Iceland	2.6	37,113	Venezuela	0.6	9115	Gambia, The	0.9	1465
Netherlands	2.2	37,051	Botswana	5.7	8872	Haiti	-0.5	1444
Hong Kong	5.0	36,290	Jamaica	0.9	8795	Bangladesh	1.1	1397
Canada	2.1	36,209	Brazil	2.4	8160	Cote d'Ivoire	0.7	1343
Sweden	2.0	35,225	Thailand	4.4	7794	Lesotho	2.4	1311
Belgium	2.5	34,625	South Africa	1.4	7589	Chad	0.9	1277
Denmark	2.1	33,909	Colombia	2.3	7529	Ghana	1.5	1239
United Kingdom	2.0	33,383	China	4.5	7434	Nepal	1.3	1212
Ireland	3.2	33,348	Peru	1.4	7280	Kenya	0.3	1206
Finland	2.6	32,162	El Salvador	1.3	6338	Tanzania	1.9	1189
Trinidad & Tobago	3.3	30,995	Tunisia	2.9	6301	Uganda	1.2	1152
France	2.3	30,822	Guatemala	1.5	6285	Benin	0.7	1116
Japan	3.4	30,008	Ecuador	1.6	6171	Rwanda	0.4	1031
Taiwan	5.8	28,694	Algeria	0.8	6070	Mali	1.3	999
New Zealand	1.4	27,865	Egypt	3.2	4956	Comoros	0.4	916
Italy	2.4	27,693	Namibia	1.3	4777	Burkina Faso	0.9	902
Spain	3.1	27,634	Jordan	1.1	4644	Sierra Leone	0.6	873
Greece	3.1	27,285	Fiji	1.6	4284	Guinea	-0.3	827

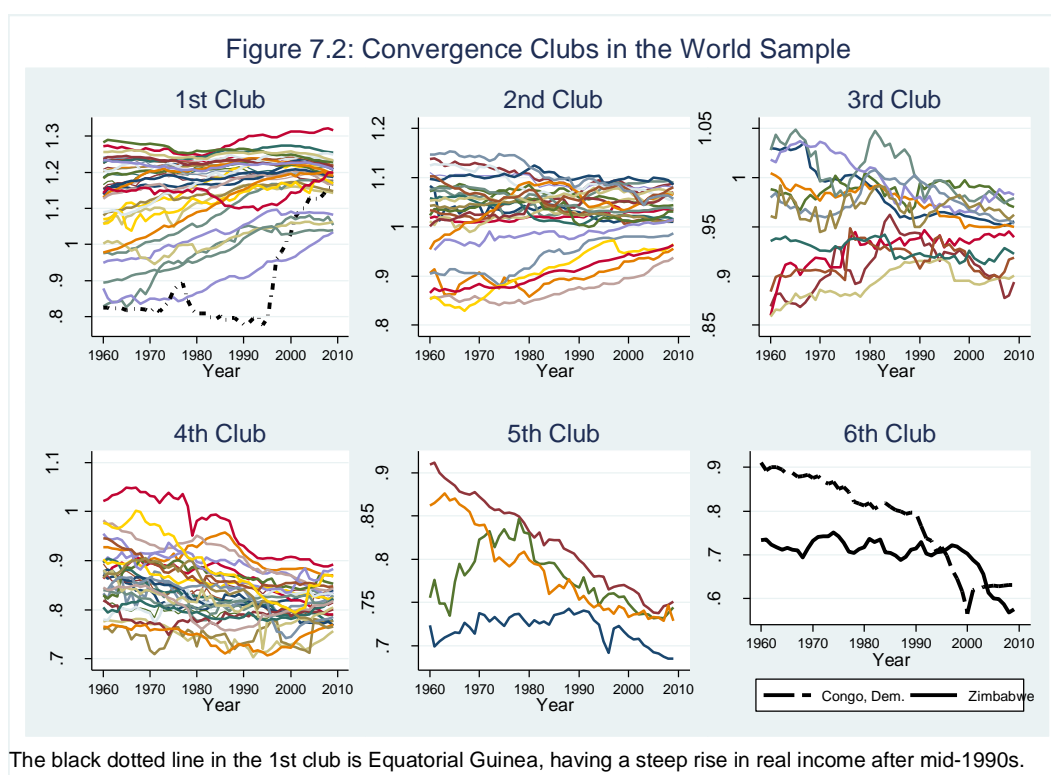
Israel	2.6	25,550	Indonesia	3.7	4075	Guinea-Bissau	1.8	818
Korea, Rep.	5.5	25,034	Sri Lanka	3.5	4035	Mozambique	1.5	759
Seychelles	3.9	23,805	Syria	1.9	4002	Madagascar	-0.2	753
Puerto Rico	2.9	23,660	Bolivia	0.7	3793	Togo	-0.1	734
Barbados	2.3	22,917	Cape Verde	2.6	3781	Ethiopia	1.2	684
Equatorial Guinea	7.8	22,031	Paraguay	1.4	3704	Central African Rep.	-1.0	648
Portugal	3.3	19,890	Honduras	1.0	3605	Malawi	1.3	611
Cyprus	3.6	18,981	Morocco	3.1	3295	Niger	-0.7	534
Chile	2.4	11,999	India	3.1	3239	Burundi	0.7	368
Argentina	1.3	11,961	Philippines	1.6	2838	Congo, Dem.	-3.1	231
Mexico	1.9	11,629	Papua New Guinea	2.3	2746	Zimbabwe	-1.4	143
Malaysia	4.2	11,296	Pakistan	2.4	2353			

Source: *Author's calculation based on Penn World Table Database.*

Notes: Countries are arranged in descending order according to their Per capita GDP level in 2009. Real income is real GDP per capita at purchasing power parity (International Dollars, I\$). Average growth is the compound annual growth rate of real GDP per capita for the period 1960-2009.

the real GDP per capita of each country in 2009. To make it more consistent with the methodology of convergence clubs described in the previous part, these countries are arranged in descending order of the real per capita income in 2009 (last time-series observation in the data). The highest average income growth figure, i.e. 7.8%, for the 1st club, belongs to Equatorial Guinea, which has double digit income growth figures for the decades of 1990s and 2000s. As already discussed in chapter 3, the discovery of large petroleum resources in 1990s may explain this high growth figure. Three other members of the 1st club have high average income growth values, namely Botswana, South Korea and Taiwan with figures being 5.5%, 5.5% and 5.8% respectively.

The 2nd club predominantly consists of Latin American & Caribbean nations (15 out of 25), with 5 countries in this club are from the African continent. With its relatively low real per capita income among European countries in 2009, Romania is also part of this club. The remaining 4 countries in the club are from Asia, with 3 of these, namely, India, Indonesia and Sri Lanka, having an average income growth of at least 3%. Convergence test results reported in column 3 of Table 7.1 are more robust for



the 1st club than for the 2nd, while they are quite weak for the 3rd club. This 3rd club consists of a mix of Asian, African and Latin American & Caribbean countries, making a total of 12. In contrast, a relatively large number (29) of developing countries are grouped into the 4th club with its size of 29, mainly consisting of the South Asian and sub-Saharan African countries. The majority of these countries are characterized by slight or no increase in their real GDP per capita over the full sample period. Indeed, the average growth figure for 19 out of 29 countries in this club is less than 1%, including some negative average growth figures, e.g. for Guinea, Haiti, Madagascar, Nicaragua, Nigeria and Togo [see Table 7.2].

The poorest 6 countries in the world sample in Table 7.2 appear in two separate clubs containing 4 and 2 members each [see Table 7.1]. The 5th club in Table 7.1 comprises Burundi, Central African Republic, Malawi and Niger while the Democratic Republic of Congo and Zimbabwe form the 6th club. The highest negative growth figure (-3.1%) is for the Democratic Republic of Congo while, Zimbabwe is the poorest country in the world with real per capita GDP of just I\$143 in 2009. More surprisingly perhaps, this value of real GDP per capita for Zimbabwe is less than the one in 1960. Growth convergence and convergence clubs for a world sample of 152 countries spanning over 1970-2003 was previously analyzed by Phillips and Sul (2009), who reported no evidence of full sample growth convergence. However, these authors indicated 5 convergence clubs and a group of diverging countries.

Table 7.1 and Figure 7.2 confirm convergence clubs of the world countries; yet an important question relates to the tendency of relative transition parameters across the convergence clubs over the time-span of 50 years. Information on this is illustrated in Panel C in Figure 7.1 with the trend in the average relative transition parameter for each of the clubs. The gap between the 1st and 2nd club has increased because of a continuous upward movement in the transition curve of the 1st club. In contrast, the distance between transition curves of the 2nd and 3rd clubs has approximately remained constant, but has increased between the 3rd and 4th clubs. The relative transition curves of the last two, though; small clubs have started diverging in the last 20 years because of declining relative transition parameters of the 6th club.

In a way, Tables 7.1 and 7.2 also shed light on the hierarchy of world countries and regions. It is already known and is evident from Table 7.1 that on the whole, Australia, North American and European countries are in the 1st or richest club. In addition, the consistent economic performance of most of the East Asian countries has also enabled them to be part of this club. In this hierarchy, this 1st club is followed by the Latin American and Caribbean countries which predominantly form the 2nd club. However, most of the South Asian countries are ‘close’ to the Latin American group by being part of either 2nd or 3rd club; still, there are exceptions like Bangladesh and Nepal in the 4th club. The greater part of the African sample, specifically sub-Saharan Africa belongs to the 4th, 5th and 6th clubs and forms the lowest in this hierarchy of world countries and regions. In this discussion, an analysis of growth convergence and convergence clubs within each region may well be a useful addition to the literature.

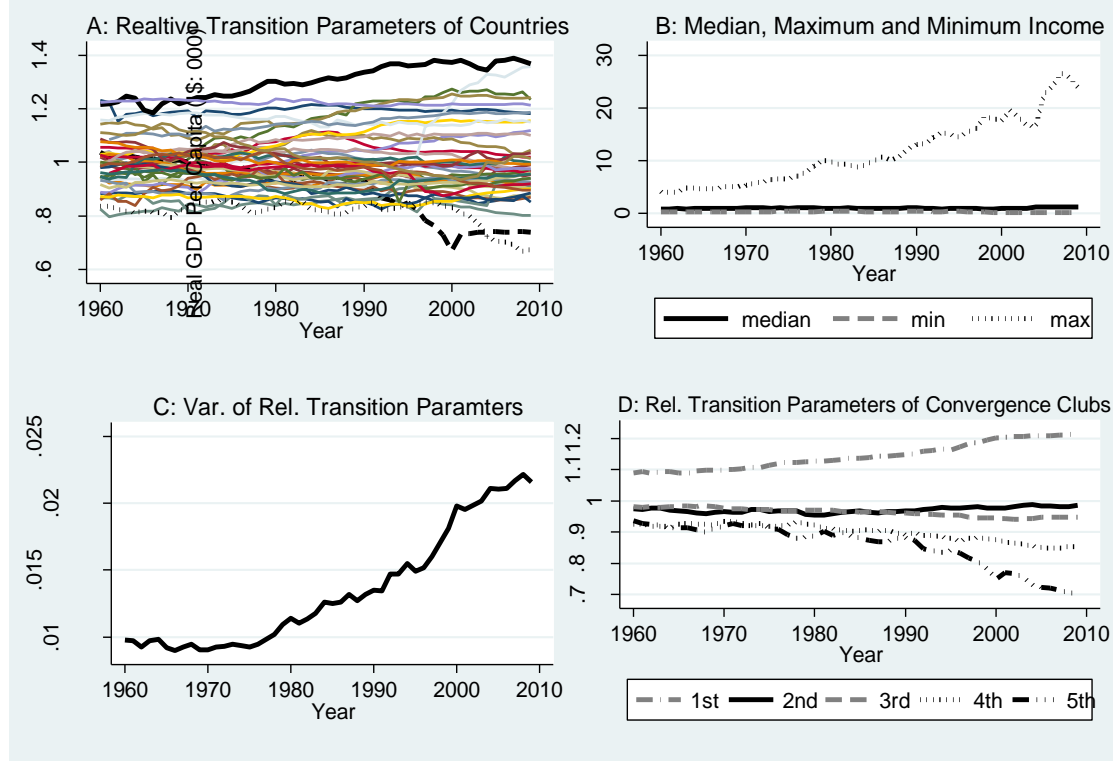
7.4.2. Results on Geographic Regions

Results on the full sample of growth convergence and convergence clubs for each of the geographic categories is given in Table 7.3. At the top of Table 7.3, growth convergence (or the $\log t$ regression test result) for the African region indicates the rejection of the null of convergence; hence confirming no conditional σ -convergence for the African countries as well. The spread of relative transition parameters of African countries has increased throughout the sample period, as illustrated by Panel A in Figure 7.3. Additionally, Panel C in this Figure depicts the steadily rising variance of the relative transition parameters of African countries, therefore confirming the finding of no growth convergence. Furthermore, a look at the trend in the descriptive statistics, minimum, maximum and median, of real income for Africa in Panel B seem to support the rising income dispersion through the decreasing minimum income and rising maximum income in the region. The minimum real income in the region has decreased from a value of I\$259 in 1960 to I\$143 in 2009. However, with the initial and final values being I\$801 and I\$1239 respectively, the median income has shown some increase over this period.

Table 7.3. Growth Convergence and Convergence Clubs in Geographic Regions

Table 7.3. Growth Convergence and Convergence Clubs in Geographic Regions			
Region/no. of countries	Full sample test results	Convergence Clubs	
		Countries in club	Test results
Africa [43]	-1.392** (-127.2)	1 st Club [11]: Algeria, Botswana, Cape Verde, Egypt, Equatorial Guinea, Mauritius, Morocco, Namibia, Seychelles, South Africa, Tunisia	0.030 (0.49)
		2 nd Club [6]: Chad, Congo Republic, Lesotho, Mali, Nigeria, Uganda	0.349 (4.13)
		3 rd Club [20]: Benin, Burkina Faso, Cameroon, Comoros, Cote d'Ivoire, Ethiopia, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Madagascar , Mauritania, Mozambique, Rwanda, Senegal, Sierra Leone, Tanzania, Togo , Zambia	0.095 (1.85)
		4 th Club [4]: Burundi, Central African Republic, Malawi, Niger	0.785 (6.64)
		5 th Club [2]: Congo Democratic, Zimbabwe	3.725 (2.83)
Asia [19]	-0.647** (-33.8)	1 st Club [10]: China, Hong Kong, Israel, Japan, Korea Republic, Malaysia, Singapore, Taiwan, Thailand, Turkey	0.345 (13.3)
		2 nd Club [9]: Bangladesh, India, Indonesia, Jordan, Nepal, Pakistan, Philippines, Sri Lanka, Syria	0.074 (1.37)
Europe [19]	-0.759** (-20.21)	1 st Club [17]: Austria, Belgium, Cyprus, Denmark, Greece, Finland, France, Iceland, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK	0.235 (5.69)
		Diverging countries [2]: Romania, Luxemburg	-
Latin America [23]	-1.290** (-21.42)	1 st Club [4]: Barbados, Chile, Puerto Rico, Trinidad &Tobago	0.170 (0.86)
		2 nd Club [11]: Argentina, Brazil, Colombia, Costa Rica, Dominican Republic, El Salvador, Jamaica, Mexico, Panama, Uruguay, Venezuela	0.655 (9.75)
		3 rd Club [4]: Ecuador, Guatemala, Paraguay, Peru	0.188 (1.75)
		4 th Club [2]: Bolivia, Honduras	1.037 (1.93)
		5 th Club [2]: Haiti, Nicaragua	0.540 (4.06)
Notes: ** indicates significance at 1* level. [.] report number of countries in particular region or club. The full sample results of log <i>t</i> test in the second column are based on separate estimations of equation (7.15) for each region. For further notes, see Table 7.1.			

Figure 7.3. Income Convergence in African Continent

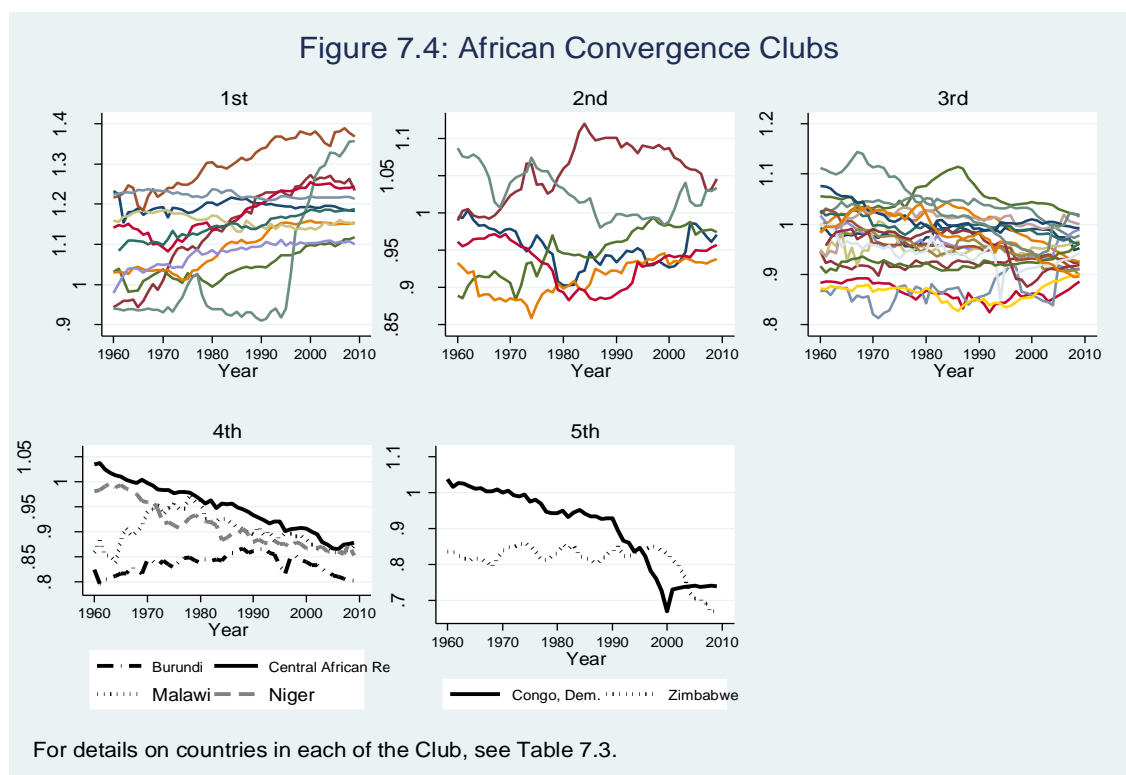


Notes: Panel A plots the relative transition parameters of all countries in the African region. The dashed and dotted lines at the bottom of the figure represent Democratic Congo and Zimbabwe respectively. The solid line at the top of all relative transition parameters is Seychelles.

Despite no growth convergence in the full sample, there is evidence of convergence clubs within the African region with a total of 5 clubs. The countries in each club, along with the result of $\log t$ regression, are reported in Table 7.3 and the graphical illustration of relative transition parameters of each club is given in Figure 7.4. This information on convergence clubs is further confirmed by the average income growth figures of each country in the African region arranged in descending order of their real income in 2009 in Table 7.4. There are 11 countries in the 1st club of the African region, which comprises the richest countries and the majority is having an average income growth of at least 2% [see Table 7.4]. Similarly, almost all of the countries in the rather small 2nd club had an annual real per capita income of at least I\$1000 in 2009. Despite being in the 2nd club in this hierarchy of countries, only 2 of the

Table 7.4. Average Income Growth Rates for Countries within Geographic Regions (1960-2009)					
Country	Avg. Growth (%)	Real Income in 2009 (international \$)	Country	Avg. Growth (%)	Real Income in 2009 (international \$)
<i>Africa</i>			Congo, Dem.	-3.1	231
Seychelles	3.9	23,805	Zimbabwe	-1.4	143
Equatorial Guinea	7.8	22,031	<i>Asia</i>		
Mauritius	3.0	9,484	Singapore	5.0	47,373
Botswana	5.7	8,872	Hong Kong	5.0	36,290
South Africa	1.4	7,589	Japan	3.4	30,008
Tunisia	2.9	6,301	Taiwan	5.8	28,694
Algeria	0.8	6,070	Israel	2.6	25,550
Egypt	3.2	4,956	Korea, Rep.	5.5	25,034
Namibia	1.3	4,777	Malaysia	4.2	11,296
Cape Verde	2.6	3,781	Turkey	2.3	9,909
Morocco	3.1	3,295	Thailand	4.4	7,794
Congo, R	2.1	2,220	China	4.5	7,434
Nigeria	0.6	2,034	Jordan	1.1	4,644
Cameroon	0.8	1,811	Indonesia	3.7	4,075
Zambia	0.0	1,765	Sri Lanka	3.5	4,035
Mauritania	2.0	1,574	Syria	1.9	4,002
Senegal	0.1	1,492	India	3.1	3,239
Gambia, The	0.9	1,465	Philippines	1.6	2,838
Cote d'Ivoire	0.7	1,343	Pakistan	2.4	2,353
Lesotho	2.4	1,311	Bangladesh	1.1	1,397
Chad	0.9	1,277	Nepal	1.3	1,212
Ghana	1.5	1,239	<i>Europe</i>		
Kenya	0.3	1,206	Luxembourg	3.3	84,525
Tanzania	1.9	1,189	Norway	2.9	49,945
Uganda	1.2	1,152	Switzerland	1.5	39,621
Benin	0.7	1,116	Austria	2.6	37,402
Rwanda	0.4	1,031	Iceland	2.6	37,113
Mali	1.3	999	Netherlands	2.2	37,051
Comoros	0.4	916	Sweden	2.0	35,225
Burkina Faso	0.9	902	Belgium	2.5	34,625
Sierra Leone	0.6	873	Denmark	2.1	33,909
Guinea	-0.3	827	U.K.	2.0	33,383
Guinea-Bissau	1.8	818	Ireland	3.2	33,348
Mozambique	1.5	759	Finland	2.6	32,162
Madagascar	-0.2	753	France	2.3	30,822
Togo	-0.1	734	Italy	2.4	27,693
Ethiopia	1.2	684	Spain	3.1	27,634
Central African R.	-1.0	648	Greece	3.1	27,285
Malawi	1.3	611	Portugal	3.3	19,890
Niger	-0.7	534	Cyprus	3.6	18,981
Burundi	0.7	368	Romania	3.9	9,737
Source: Author's calculations based on Penn World Table database					
Notes: see Table 7.2.					

6 countries have an average income growth figure of above 2%, while 2 of these countries also have less than 1% income growth over the period 1960-2009. The situation concerning both the average income growth and the real income level in 2009 in the 3rd club starts getting worse with most of the countries having less than 1% income growth over 50 years' time span [see Table 7.4].



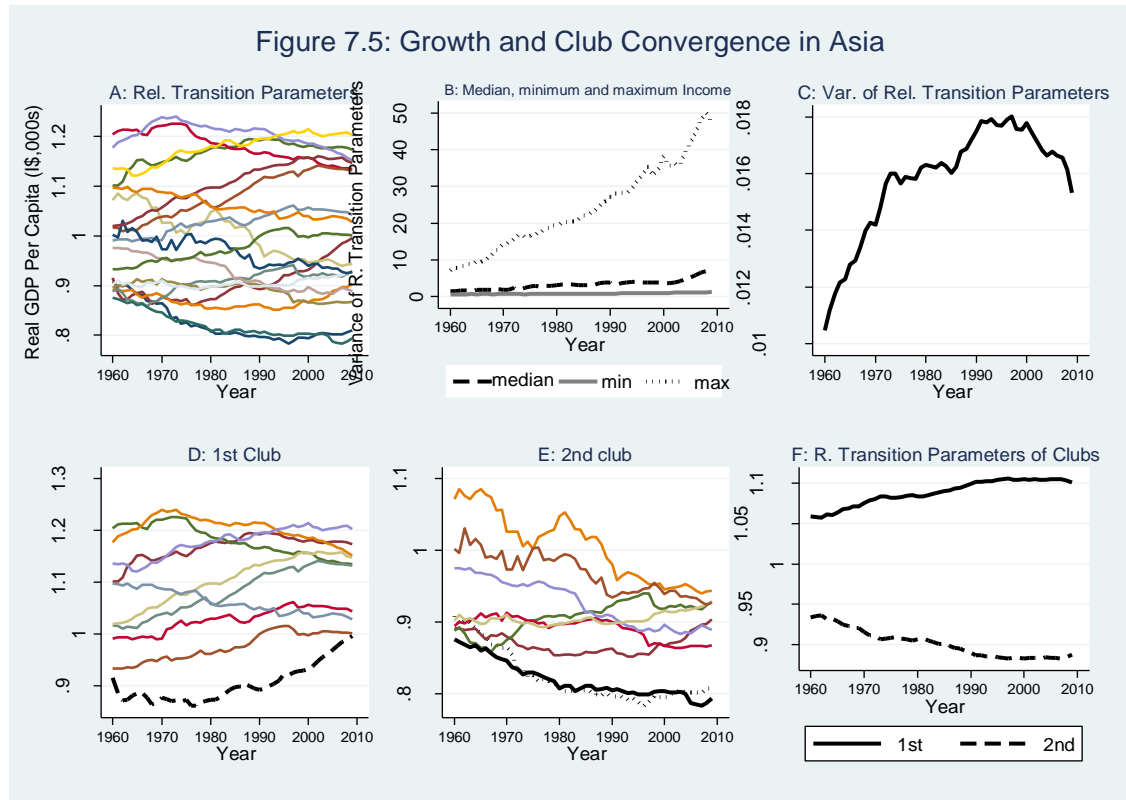
The remaining two convergence clubs in the African region are small in size; as the 4th and 5th club have 4 and 2 member countries respectively. According to Figure 7.4 all these 6 countries experience a declining trend of the relative transition parameters. Exactly similar to the convergence clubs of the world sample, the 4th club in the African region includes Burundi, Central African Republic, Malawi, Niger and the 5th club comprises Congo Democratic and Zimbabwe. All these countries are the six poorest countries in each case. However, the real per capita incomes of countries in 4th club, namely, Malawi and Central African Republic, are approximately thrice the income levels of Democratic Republic of Congo and Zimbabwe. Moreover, the former two

countries also have similar relative transition paths after 1980s [see Figure 7.4]. A possible cause for the highest negative income growth in the case of the Democratic Republic of Congo has already been explained in chapter 3 in the analysis of absolute β and absolute σ convergence. While for Zimbabwe, after a fluctuating trend in real GDP till about mid-1990s, a steep fall follows till 2009. Clemens and Moss (2005) explain the economic collapse of Zimbabwe as the result of *poor governance*. Clemens and Moss (2005, p. 4) also reported that “*Harvard’s Samantha Power even used Zimbabwe as an example of **how to kill a country***”.

The average relative transition parameters for 5 African convergence clubs are plotted in Panel D in Figure 7.3. The curve for the first club has a rising trend while, quite opposite is the case for all other four clubs, specifically, for the 5th club, whose curve has a continuous declining tendency. There is no visible gap between the average relative transition parameters of 2nd and 3rd clubs but 4th and 5th clubs have moved away from 2nd and of course from 1st club as well. Therefore, considerable evidence of divergence across clubs can be concluded from this figure.

In contrast to the African economic performance, Asian countries have relatively consistent and better income growth figures as given in the 4th column of Table 7.4. More than half of these sample countries have an average income growth of at least 3%. In Panel B of Figure 7.5, the maximum income in the region has shown a continuous increase from I\$7053 to I\$47373. While, an apparently small increase in the median income is actually from I\$1470 to I\$7433 over the period 1960 to 2009. However, the minimum income has also doubled in the sample period. But the growth convergence test fails to accept the null of convergence for the Asian region [see Table 7.3]. The cross-sectional variance in Panel C of Figure 7.5 has increased during the first 30 years of the sample period, and has declined afterwards. This decline is steep in the recent five years (2005-09) in which the median income of the region also has shown a relatively sharp rise. The relative transition parameters for the full sample in Panel A of Figure 7.5 are also indicating an increasing spread over time.

Moreover, the relative transition parameters of convergence clubs in Panel D and Panel E are characterized with a reduced spread. The list of countries for these two Asian clubs is given in Table 7.3 and the related information on real GDP per capita of 2009 and average income growth rates is given in Table 7.4. The 1st and relatively rich club constitutes East Asian countries and Turkey, while the South Asian countries together with Jordan, Syria and Philippines are part of the 2nd club. In panel D of Figure

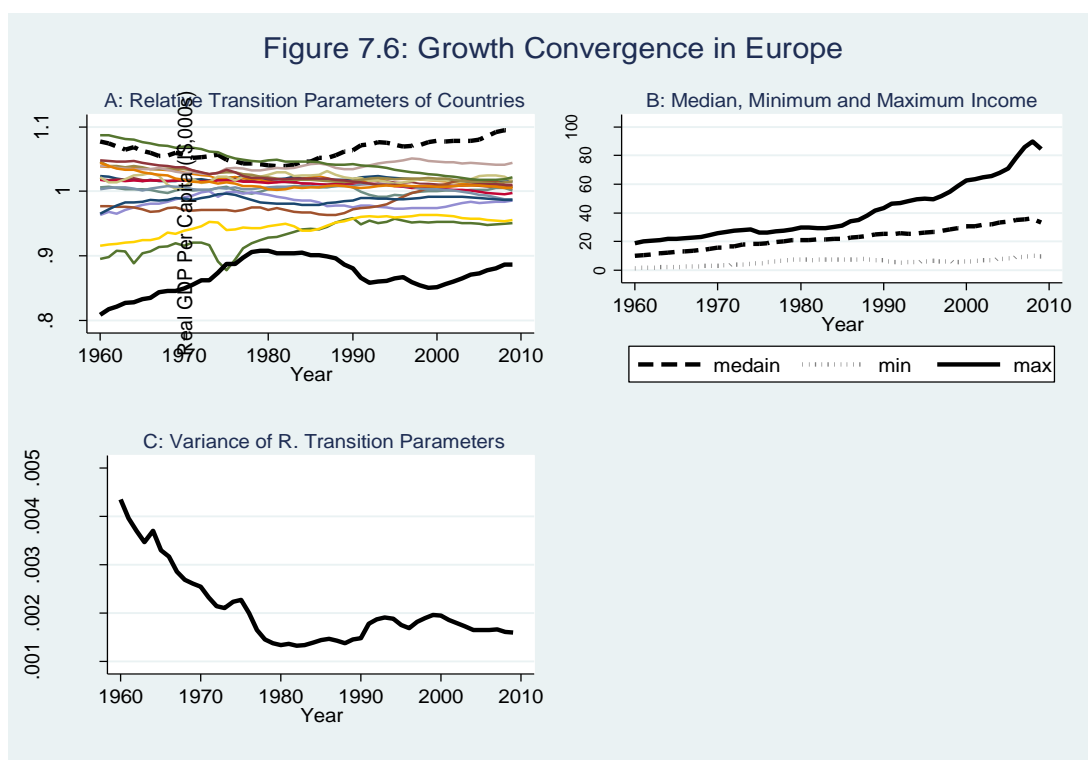


Notes: Panel B illustrates median, minimum and maximum real income of the Asian sample countries. The dashed line in panel D refers to China, and the solid and dotted lines at the bottom of panel E represent Nepal and Bangladesh respectively. For details on countries in each club, see Table 7.3.

7.5, the catching-up country at the bottom of the 1st club is China, while the bottom two countries in the 2nd club represent the poorest in the Asian sample, namely Bangladesh and Nepal with the average income growth of 1.1% and 1.3% respectively [see Table 7.4]. Estimated values of \hat{b} in log t regressions of each club, reported in the 4th column of Table 7.3, indicate a much higher coefficient for the 1st club compared to that of the 2nd club. This illustrates relatively strong convergence among the countries in the 1st club

compared to that in the 2nd club. Finally, the average relative transition parameters for the 1st and 2nd club are plotted in Panel F in Figure 7.5. It illustrates a diverging pattern between the two clubs with a steadily rising curve for the 1st club and a declining tendency in the 2nd one.

The convergence club analysis for the world sample indicated a majority of the European countries being part of the richest club. The growth convergence test results for the European region are reported in Table 7.3 and the relative transition parameters are described in Panel A of Figure 7.6. These transition parameters are indicating a reduced spread among the European region except for the two diverging economies as the outliers at the top and at the bottom representing Luxemburg and Romania



Notes: Panel A plots the relative transition parameters of all countries in the European region. The dashed and solid lines at the top and bottom of the figure represent Luxemburg and Romania respectively, which are the two diverging economies in the EU.

respectively. There is no evidence of growth convergence for the European region in the $\log t$ regression results reported in Table 7.3. However, the variance of the relative

transition parameter has decreased in this region and there is a considerable increase both in the median and minimum European income over the period 1960-2009 [see Panel B & C in Figure 7.5]. The convergence club analysis has confirmed a single club of 17 out of 19 European countries; excluding Luxemburg and Romania. Besides, it is evident from Table 7.4, that the real GDP per capita of Luxemburg is approximately twice the real income level of the 2nd richest country in the sample while, the converse holds for the real income level of Romania with its real income in 2009 being almost half of that for Cyprus. In an earlier study of EU-14 countries covering the period 1980-2004, Apergis et al. (2010) have also concluded no growth convergence for the overall sample, and a convergence club consisting of all countries except Greece.

The last geographic region in the list is Latin America & Caribbean. Similar to the full sample growth convergence results for other geographic regions in Table 7.3, there is also no evidence of growth convergence for this region as a whole. Relative transition parameters for the full sample in Panel A of Figure 7.7 indicate no evidence in favour of $\delta_{it} \rightarrow \delta$ while the cross-sectional variance of the relative transition parameters has increased over the period 1960-2009; though there was a decrease in this variance during 1970s [Panel C in Figure 7.7]. The minimum real income of the sample has decreased from a value of I\$1847 to I\$1444 and both of these values belong to Haiti. However, the median income of the sample has doubled. There is also an overall increasing trend in the maximum income and the value in 2009 is four times the value in 1960 (I\$30,995 and I\$7648 respectively).

With no evidence for the full sample growth convergence, there are 5 convergence clubs within the Latin American & Caribbean region. The 1st club in the region listed in Table 7.3 consists of 4 countries whose relative transition parameters are illustrated in Figure 7.8. Chile is below the three other Caribbean countries, Barbados, Puerto Rico and Trinidad & Tobago, in the 1st club. It is also clear from Table 7.5 that the real income of Chile is approximately half of that for Barbados which currently is the 3rd richest country in the region followed by Trinidad & Tobago and Puerto Rico. The relatively large 2nd club consists of 11 countries with a reasonable size of the estimated

Figure 7.7: Convergence in Latin America & Caribbean

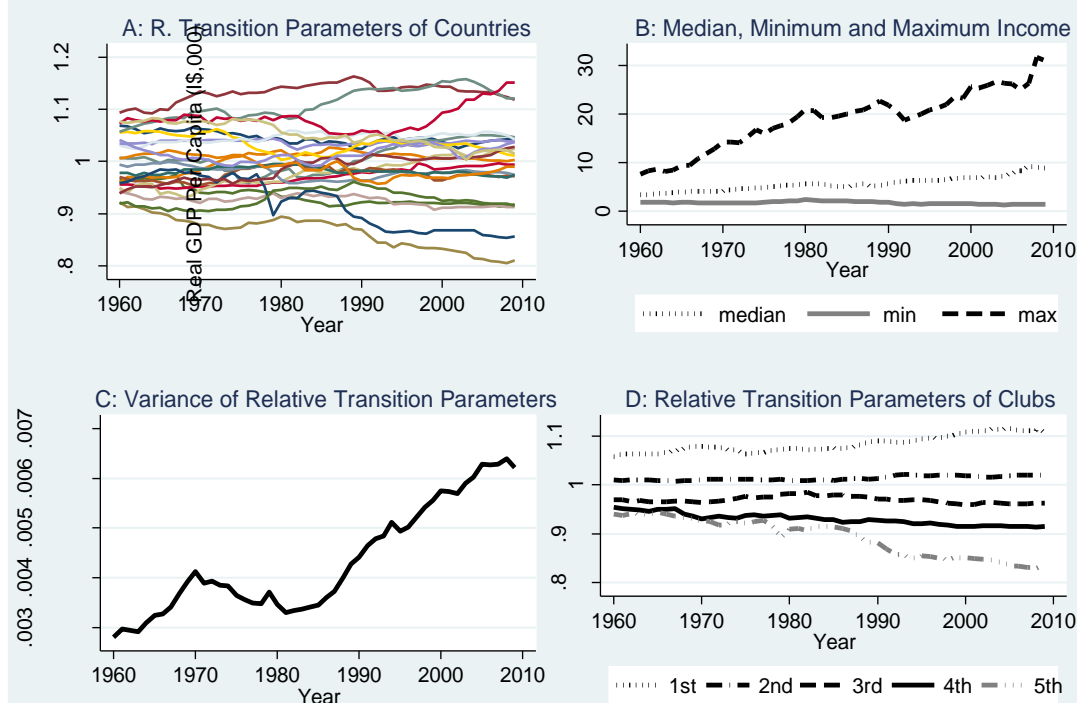
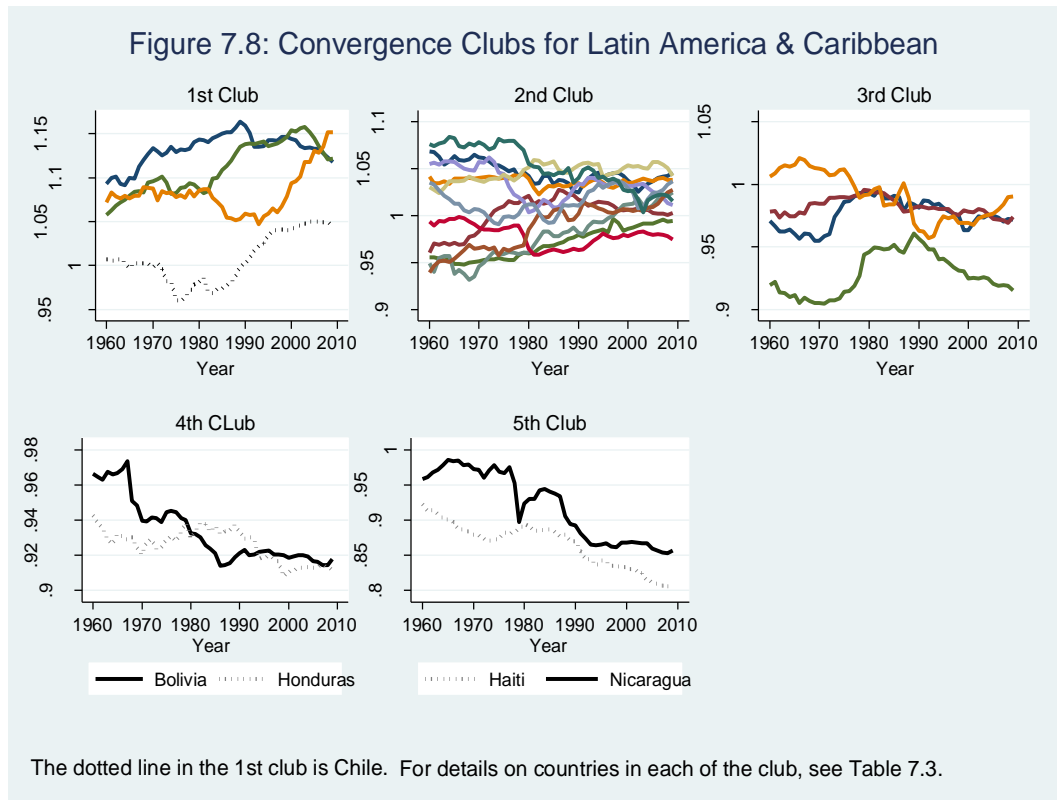


Table 7.5. Growth and Real GDP in Latin American Countries

Country	Avg. Growth (%)	Real Income in 2009 (I\$)	Country	Avg. Growth (%)	Real Income in 2009 (I\$)
Trinidad & Tobago	3.3	30,995	Brazil	2.4	8,160
Puerto Rico	2.9	23,660	Colombia	2.3	7,529
Barbados	2.3	22,917	Peru	1.4	7,280
Chile	2.4	11,999	El Salvador	1.3	6,338
Argentina	1.3	11,961	Guatemala	1.5	6,285
Mexico	1.9	11,629	Ecuador	1.6	6,171
Costa Rica	1.7	11,217	Bolivia	0.7	3,793
Uruguay	1.7	11,069	Paraguay	1.4	3,704
Panama	3.2	10,198	Honduras	1.0	3,605
Dominican Rep.	3.0	9,911	Nicaragua	-0.3	2,192
Venezuela	0.6	9,115	Haiti	-0.5	1,444
Jamaica	0.9	8,795			
Source: Author's calculations based on Penn World Table database					
Notes: see Table 7.2.					



\hat{b} coefficient in the $\log t$ regression. These countries have varying values of average income growth reported in Table 7.5 and have a value of at least \$7500 for the real income in 2009. The remaining three clubs, 3rd, 4th and 5th respectively consists of 4, 2 and 2 members. The two poorest countries with their negative average income growth are Haiti and Nicaragua. According to De Gregorio and Lee (1999), low levels of human capital and poor economic institutions explain the low income growth of these two Latin American countries. It is worth noting that the two poorest countries in the Latin American sample, Haiti and Nicaragua, have higher real income levels than the two poorest in the Asian sample, Bangladesh and Nepal.

A look at the trend of average relative transition parameters across-clubs in Panel D of Figure 7.7 reveals that the 1st and 5th club are diverging with the former moving upwards and vice versa for the latter. An upward trend of the 1st club has increased the distance between the 1st and 2nd club while, the gaps between the 2nd and 3rd clubs and between 3rd and 4th clubs in 2009 have approximately stayed at their level in 1960. As

mentioned earlier, the declining trend in the relative transition parameters of the 5th club is resulting in divergence between the 4th and 5th clubs.

7.4.3. Results on Income Categories

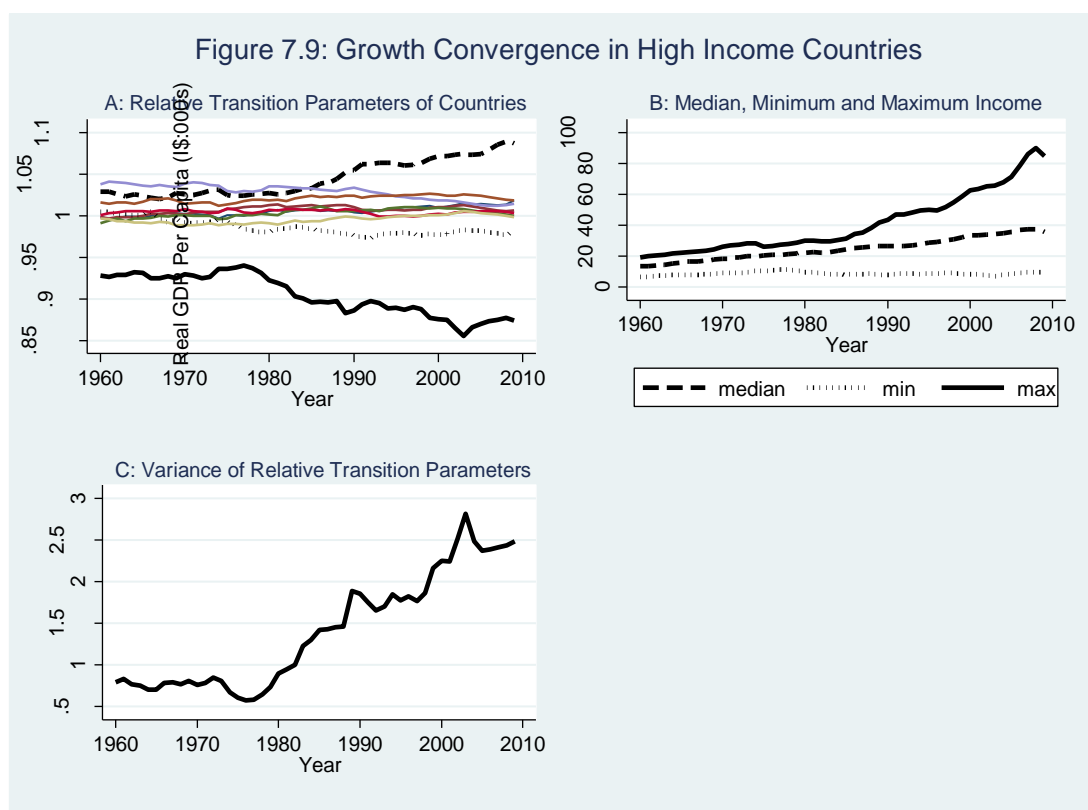
A second way of looking at the world sample is to apply the $\log t$ test centered on equation (7.15) on various income categories of the world sample to investigate the converging behaviour of previously high, upper middle, lower middle and low income countries during the past 50 years (these categories are based on their income level at the beginning of the sample period as previously defined in chapter 2). The result of the full sample $\log t$ test for the high income cluster is reported in Table 7.6. The null hypothesis of growth convergence is rejected for these 10 countries which are having an increasing trend in the variance of their relative transition parameters depicted in Panel C in Figure 7.9. The median, minimum and maximum, all three values of real income have increased for the high income group [see Panel B in Figure 7.9]. By the mid of 1980s, there was only a small difference between the median and maximum real income, but this gap has increased afterwards and the median and maximum values in 2009 are equal to I\$35,717 and I\$84,525 respectively.

Relative transition parameters of high income countries in Panel A in Figure 7.9 illustrate converging patterns for most of the sample countries except for Venezuela at the bottom and Luxemburg at the top. The relative transition curve for New Zealand has also moved away from the remaining cluster of transition parameters after the mid-1980s. The application of the convergence club test confirms a single club of high income countries consisting of 7 members. The 3 diverging economies are Luxemburg, New Zealand and Venezuela [see Table 7.6]. Figures for average income growth and real GDP per capita of 2009 reported in Table 7.7 also help explain these results on convergence clubs. According to per capita income figures of 2009 for high income category, Luxemburg has a very high income compared to the 2nd in the hierarchy, Australia. While New Zealand and Venezuela have lowest incomes in this category [see Table 7.7].

Table 7.6. Growth Convergence and Convergence Clubs: Income Categories (1960-2009)			
Region/no. of countries	Full sample test results	Convergence Clubs	
		Countries in club	Test results
High income [10]	-1.848** (-116.9)	1 st Club [7]: Australia, Canada, Denmark, Sweden, Switzerland, UK, USA	0.814 (7.982)
		Diverging countries [3]: Luxemburg, New Zealand, Venezuela	-
Upper middle income [13]	-0.387** (-7.92)	1 st Club [11]: Austria, Belgium, Chile, Finland, France, Iceland, Ireland, Italy, Netherlands, Norway, Trinidad &Tobago	0.073 (0.90)
		2 nd Club [2]: Argentina, Uruguay	2.54 (44.9)
Lower middle income [22]	-1.02** (-25.3)	1 st Club [11]: Barbados, Cyprus, Greece, Hong Kong, Israel, Japan, Mauritius, Portugal, Puerto Rico, Singapore, Spain	0.101 (1.51)
		2 nd Club [5]: Colombia, Costa Rica, Mexico, Panama, South Africa	0.21 (7.18)
		3 rd Club [4]: Ecuador, Guatemala, Peru, Syria	0.448 (8.45)
		4 th Club [2]: Bolivia, Namibia	-0.169 (-0.86)
Low income [65]	-1.25** (-399.5)	1 st Club [14]: Botswana, Brazil, China, Dominican Republic, El Salvador, Equatorial Guinea, Jamaica, Korea Republic, Malaysia, Romania, Seychelles, Taiwan, Thailand, Turkey	0.186 (2.82)
		2 nd Club [16]: Algeria, Cape Verde, Congo Republic, Egypt, Fiji, Honduras, India, Indonesia, Jordan, Morocco, Pakistan, Papua New Guinea, Paraguay, Philippines, Sri Lanka, Tunisia,	0.225 (3.34)
		3 rd Club [29]: Bangladesh, Benin, Burkina Faso, Cameroon, Chad, Comoros, Cote d'Ivoire, Ethiopia, Gambia, Ghana, Guinea, Guinea Bissau, Haiti, Kenya, Lesotho, Madagascar, Mali, Mauritania, Mozambique, Nepal, Nicaragua, Nigeria, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Zambia	0.112 (1.77)
		4 th Club [4]: Burundi, Central African Republic, Malawi, Niger	0.726 (10.32)
		5 th Club [2]: Congo Democratic, Zimbabwe	2.02 (2.39)
Notes: see Table 7.3.			

Table 7.7. Average Income Growth Rates for Countries within Geographic Regions (1960-2009)					
Country	Avg. Growth (%)	Real Income in 2009	Country	Avg. Growth (%)	Real Income in 2009
High Income			Low Income (continued.....)		
Luxembourg	3.3	84,525	Jamaica	0.9	8,795
Australia	2.4	41,304	Brazil	2.4	8,160
United States	2.0	41,099	Thailand	4.4	7,794
Switzerland	1.5	39,621	China	4.5	7,434
Canada	2.1	36,209	El Salvador	1.3	6,338
Sweden	2.0	35,225	Tunisia	2.9	6,301
Denmark	2.1	33,909	Algeria	0.8	6,070
United Kingdom	2.0	33,383	Egypt	3.2	4,956
New Zealand	1.4	27,865	Jordan	1.1	4,644
Venezuela	0.6	9,115	Fiji	1.6	4,284
Upper Middle Income			Indonesia	3.5	4,075
Norway	2.9	49,945	Sri Lanka	3.5	4,035
Austria	2.6	37,402	Cape Verde	2.6	3,781
Iceland	2.6	37,113	Paraguay	1.4	3,704
Netherlands	2.2	37,051	Honduras	1.0	3,605
Belgium	2.5	34,625	Morocco	3.1	3,295
Ireland	3.2	33,348	India	3.1	3,239
Finland	2.6	32,162	Philippines	1.6	2,838
Trinidad & Tobago	3.3	30,995	Papua New Guinea	2.3	2,746
France	2.3	30,822	Pakistan	2.4	2,353
Italy	2.4	27,693	Congo, R	2.1	2,220
Chile	2.4	11,999	Nicaragua	-0.3	2,192
Argentina	1.3	11,961	Nigeria	0.6	2,034
Uruguay	1.7	11,069	Cameroon	0.8	1,811
Lower Middle Income			Zambia	0.0	1,765
Singapore	5.0	47,373	Mauritania	2.0	1,574
Hong Kong	5.0	36,290	Senegal	0.1	1,492
Japan	3.4	30,008	Gambia, The	0.9	1,465
Spain	3.1	27,634	Haiti	-0.5	1,444
Greece	3.1	27,285	Bangladesh	1.1	1,397
Israel	2.6	25,550	Cote d'Ivoire	0.7	1,343
Puerto Rico	2.9	23,660	Lesotho	2.4	1,311
Barbados	2.3	22,917	Chad	0.9	1,277
Portugal	3.3	19,890	Ghana	1.5	1,239
Cyprus	3.6	18,981	Nepal	1.3	1,212
Mexico	1.9	11,629	Kenya	0.3	1,206
Costa Rica	1.7	11,217	Tanzania	1.9	1,189
Panama	3.2	10,198	Uganda	1.2	1,152
Mauritius	3.0	9,484	Benin	0.7	1,116
South Africa	1.4	7,589	Rwanda	0.4	1,031
Colombia	2.3	7,529	Mali	1.3	999
Peru	1.4	7,280	Comoros	0.4	916
Guatemala	1.5	6,285	Burkina Faso	0.9	902
Ecuador	1.6	6,171	Sierra Leone	0.6	873
Namibia	1.3	4,777	Guinea	-0.3	827

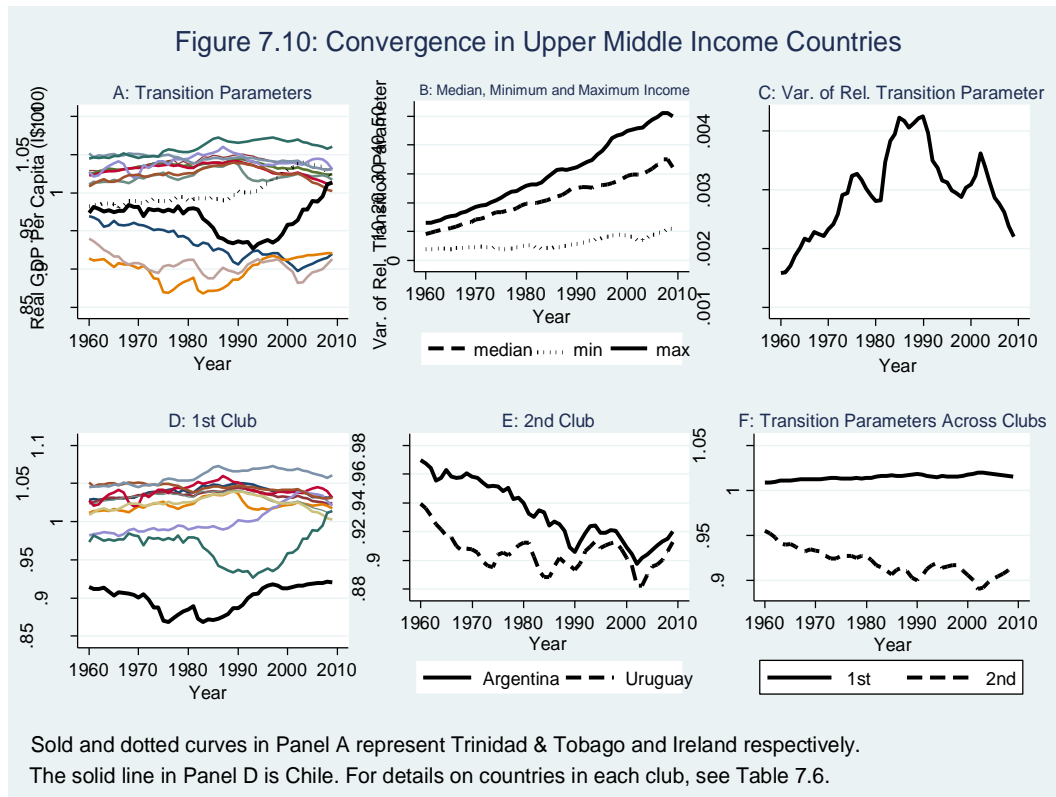
Syria	1.9	4,002	Guinea-Bissau	1.8	818
Bolivia	0.7	3,793	Mozambique	1.5	759
Low Income			Madagascar	-0.2	753
Taiwan	5.8	28,694	Togo	-0.1	734
Korea, Republic of	5.5	25,034	Ethiopia	1.2	684
Seychelles	3.9	23,805	Central African Rep.	-1.0	648
Equatorial Guinea	7.8	22,031	Malawi	1.3	611
Malaysia	4.2	11,296	Niger	-0.7	534
Dominican Republic	3.0	9,911	Burundi	0.7	368
Turkey	2.3	9,909	Congo, Dem.	-3.1	231
Romania	3.9	9,737	Zimbabwe	-1.4	143
Botswana	5.7	8,872			
Source: Author's calculations based on Penn World Table database					
Notes: see Table 7.2.					



Notes: The solid line at the bottom of Panel A represent Venezuela, while, the dotted line in the middle of the same graph is New Zealand. The dashed line at the top in Panel A is showing Luxemburg.

Similar to the high income countries, there is no evidence of growth convergence in the upper middle income group which comprises 13 countries [see Table 7.6]. The graph of relative transition parameters for the full sample is presented in Panel A in

Figure 7.10. These relative transition parameters have mixed patterns with an example of catching-up of a country e.g. Ireland. On the other hand, Trinidad and Tobago has first shown transitional divergence and later its transitional curve has rejoined the upper part of the cluster. The median and maximum real income has increased, but the gap between the two has also increased after 1980s. The minimum income of the sample has climbed from I\$3,780 to I\$11,069 in the 50



years' time period. Quite contrary to the previous graphs on the variance of relative transition parameters, the curve in Panel C of Figure 7.10 is roughly of an inverted U shape. It illustrates an initial increase in the variance till about the mid-1980s, which is followed by a fluctuating decrease till 2009.⁹⁹ The decreasing variance of the relative

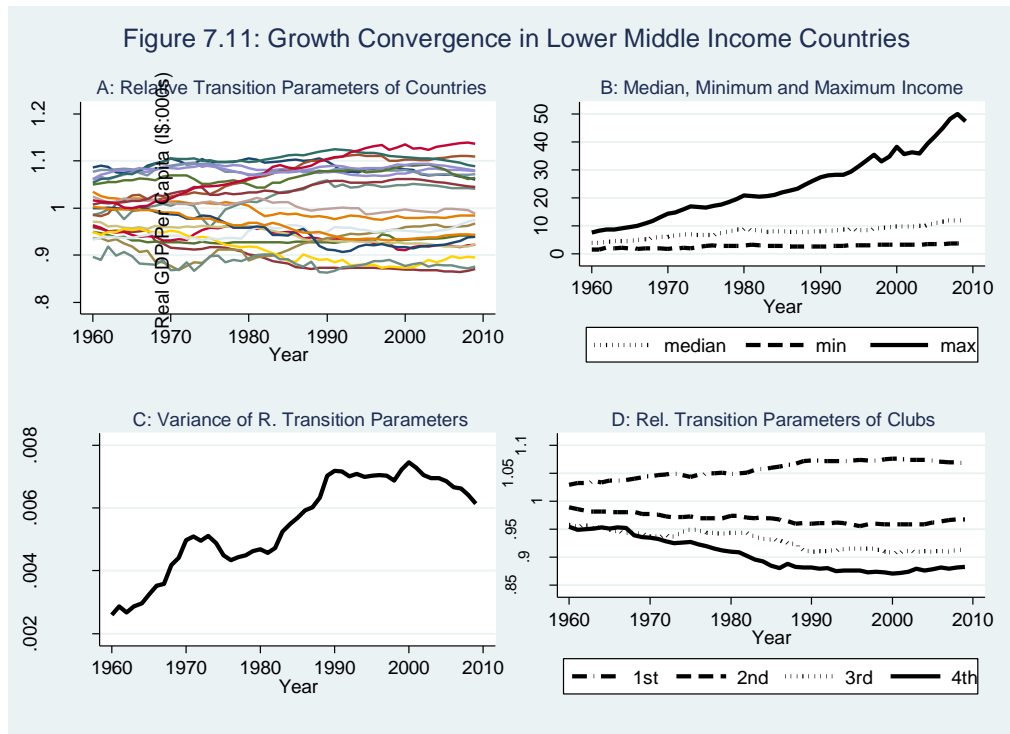
⁹⁹ This may be partially explained by the higher average income growth figures for some of the sample countries over the period 1986-2009 compared to their respective values for 1960-1985.

transition parameters over the 2nd half of sample period may indicate a sub-period of growth convergence for the upper middle income countries.

However, this upper middle income group is divided into 2 convergence clubs containing 11 and 2 countries respectively. Argentina and Uruguay make up the 2nd club, while the remaining countries comprise the 1st club. However, the estimated \hat{b} coefficient in the $\log t$ regression, reported in Table 7.6, is very small for the 1st club. Though, Chile is at the bottom of the 1st club and according to Table 7.7 its per capita income level is not much different to those of Argentina and Uruguay; yet, the trend in the relative transition parameter for Chile is different to those other two countries. Finally, Panel F in Figure 7.10 depicts the average relative transition parameters across the two clubs. The gap between two curves has increased because of an overall decreasing trend in the 2nd curve (2nd club) and an approximate constant line for the 1st club.

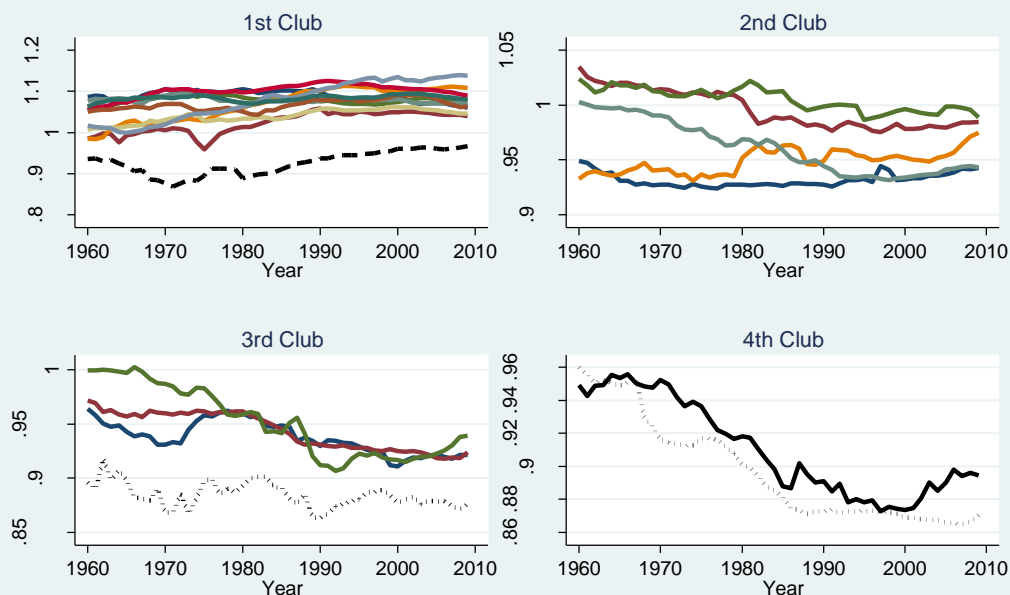
The lower middle income sample is the next to be analyzed in this income hierarchy of world countries. According to Table 7.6, there is no evidence of growth convergence for the full sample of lower middle income countries. Similarly, the relative transition parameters in Figure 7.11 also indicate an increasing spread in 2009 compared to that in 1960. Beginning from a value of I\$1600 in 1960, the minimum real income in the sample has increased to I\$3793 in 2009, while, the median value of real income has increased by three times during this period. Besides, Panel B in Figure 7.11 illustrates a continuously rising maximum real income. The variance of the relative transition parameters has increased over time, though it has shown some declining tendency in the recent years [see Panel C in Figure 7.11].

Results on the test of convergence clubs confirmed 4 clubs among the lower middle income countries which are listed in Table 7.6 and their relative transition parameters are illustrated in Figure 7.12. The 1st club consists of 11 countries and the lowest relative transition curve in Panel A of Figure 7.12 is for Mauritius. The 1st club includes some European countries e.g. Cyprus, Greece, Portugal and Spain together with the two fastest growing East Asian countries, namely Hong Kong and Singapore. Four



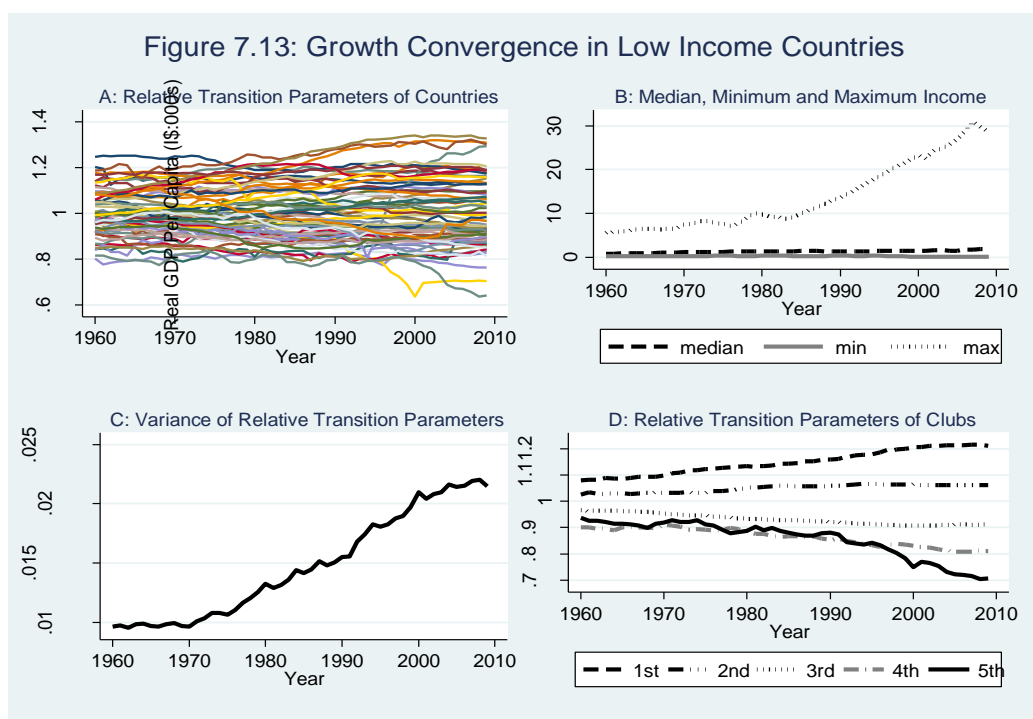
Latin American countries, Colombia, Costa Rica, Mexico and Panama together with South Africa form the 2nd club. The 3rd and 4th clubs comprise of 4 and 2 member countries respectively. The real per capita GDP level in 2009 for Bolivia and Namibia is not much different than that for Syria. However, the trend in the transition parameters for Syria is different than those for Bolivia and Namibia. Syria is part of a 3rd club while the latter two countries are included in the 4th club. Moreover, the average income growth figure for Syria is higher than those for Bolivia and Namibia [see Table 7.7]. The average relative transition parameters curve for the 1st club in Panel D of Figure 7.11 is steadily rising, but is somewhat falling for the 2nd club. However, with some fluctuations, the distance between the average relative transition parameters of 2nd and 3rd club and between 3rd and 4th club have increased [see Panel D Figure 7.11]. Alternatively, this may indicate that these clubs are illustrating diverging pattern overtime.

Figure 7.12: Convergence Clubs for Lower Middle Income Countries



The dashed line in 1st club represents Mauritius and dotted line in 3rd club denote Syria.
For details on countries in each club, see Table 7.6.

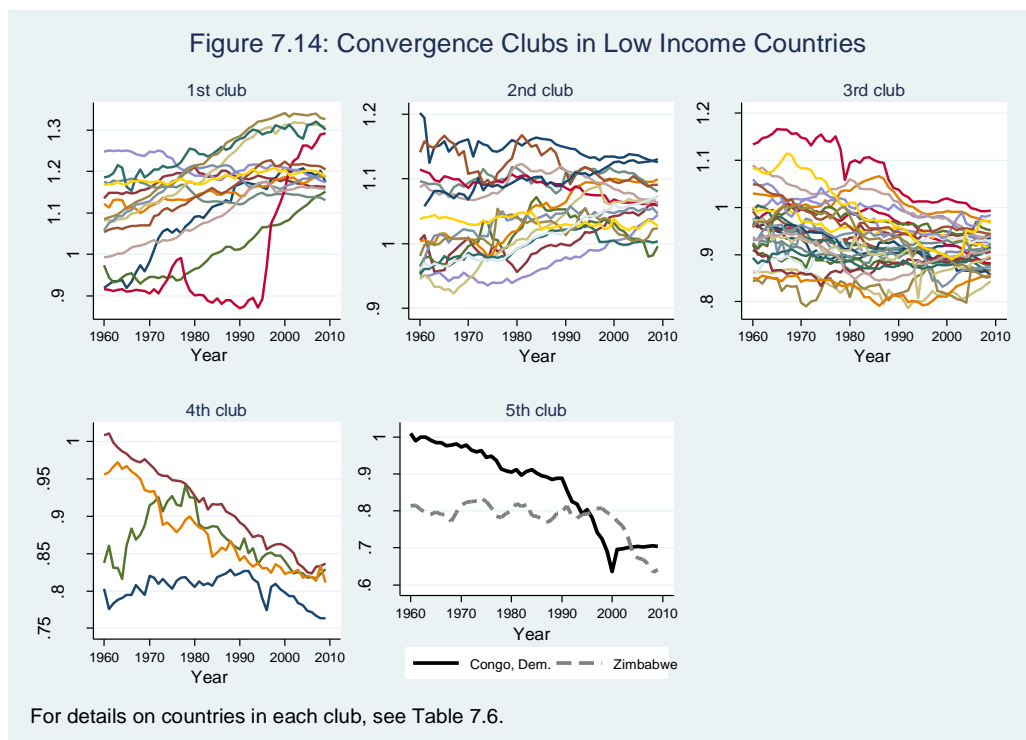
The largest cluster in terms of the number of countries is the low income one comprising 65 countries. According to the reported results in Table 7.6, with a t-statistics of -399.5, the null hypothesis of overall growth convergence is rejected at the 1% level for this cluster. Consistent with this, the variance of the relative transition parameters in Panel C of Figure 7.13 has steadily increased throughout the period 1960-2009. No evidence of growth convergence is illustrated by the relative transition curves for all the low income countries in Panel A of Figure 7.13. The steep increase in the maximum income for the cluster co-exists with a decrease in the minimum income during the 50 years' time span [see Panel B in Figure 7.13]. While, the median real income for the low income cluster has increased from I\$887 to I\$1,811.



In contrast to the evidence of no growth convergence for the full sample, there is an indication of 5 convergence clubs among the low income group, which are listed in Table 7.6 and are plotted in Figure 7.14. The 1st club consists of 14 countries including some of the faster growing East Asian and African economies, one European country Romania, and a few Latin American countries. As already mentioned, Botswana and Equatorial Guinea have the highest income growth in the African region with the respective figures of 5.7% and 7.8%. While, the average income growth for another African country Seychelles is 3.9% [see Table 7.7]. The 2nd club consists of 16 countries belonging to Asia, Africa and Latin America & Caribbean. Not all of these countries have high average income growth figures as reported in Table 7.7. The three fastest income growing economies in the 2nd club are Indonesia, Sri Lanka and Egypt with their respective figures of 3.7%, 3.5% and 3.2%.

The 3rd convergence club for low income countries listed in Table 7.6 is relatively large in number with 29 countries. A substantial number of these countries are

from sub-Saharan Africa, while some of the poorest countries from Asia and Latin American, namely, Bangladesh, Nepal and Haiti are also part of this club. The poorest 6



countries in the world sample, which not only are part of low income countries in the initial year but are lowest according to the real GDP per capita of 2009, are divided into two convergence clubs in Table 7.6. Results on convergence clubs are consistent with those reported in Table 7.1. It is worth noting that the 5th and 6th clubs in the world sample and 4th and 5th club in the African sample are identical to 4th and 5th clubs for the low income countries respectively. In addition, the Democratic Republic of Congo and Zimbabwe are at the bottom in Table 7.7, and the average value of their relative transition parameters also has a declining trend in Panel D of Figure 7.13. In contrast, the trends in the average relative transition parameters of the 1st and 2nd clubs are rising, but the gap between the two has increased over time. Similarly, the 2nd and 3rd clubs are also diverging from each other due to a slightly declining movement in the latter. A similar story related to the trend between the 3rd and 4th clubs is evident. Finally,

beginning from a point above the 4th club in 1960 and having intersecting curves afterwards, the 5th club has started diverging after the mid-1990s until the recent year, 2009.

7.5. CONCLUSIONS

The notion of growth convergence is analyzed in this chapter utilizing the recently developed technique by Phillips and Sul (2007a). This measure of convergence involves the reduced dispersion of relative transition coefficients of income whilst taking into account the variability in the speed of convergence across countries and over time. The analysis on 110 world countries suggests no overall growth convergence, but 6 convergence clubs of these countries. In fact, there are 4 large clubs comprising 104 countries and the remaining 2 clubs constitute the poorest 6 African countries in the world. These 6 countries are also distinctly grouped in clubs within separate samples of African and low income clusters.

There is also no evidence of overall growth convergence for each of the geographic categories. As, the $\log t$ regression test fails to accept the null hypothesis of growth convergence for Africa, Asia, Europe and Latin America & Caribbean. However, there is evidence of convergence clubs within each of the geographic cluster. The number of clubs varies from a minimum of just 1 club for Europe to a maximum of 5 clubs within each, the African and Latin America and Caribbean region. These results indicate that the majority of the European countries are converging. While, roughly speaking, East Asian and South Asian countries are divided into two separate clubs; since, the number of convergence clubs for Asia is 2. In contrast to these two regions, there are 5 convergence clubs within the Latin American & Caribbean region. Typically, none of the convergence clubs within each region has shown any evidence of catching-up towards each other over the study period. This result not only verifies the evidence of no overall convergence for each group but also indicates regional disparities. An examination of convergence clubs among various income clusters illustrate three Latin American countries, namely, Venezuela, Argentina and Uruguay being excluded from

the top club of high and upper middle income countries. Chile is the only Latin American country in the 1st club of the upper middle income countries along with another Caribbean country, Trinidad and Tobago. Regarding the study on convergence clubs, one debatable matter can be the relevance of two member clubs of countries compared to a very large club.

It is worth noting that the member countries of convergence clubs in the world sample do not completely match with the respective list of countries in convergence clubs of various geographic regions (income categories); however, there is some overlap between the two. For example, countries categorized in the 1st club of the world sample are not always together in the 1st club of any geographic region/income category (in which ever respective category they are part of). This may be because of varying sample sizes and variations across the samples.

A look at the real GDP per capita figures of 2009 and at other descriptive statistics of real income for various sample categories indicates that among all geographic regions, Europe and Asia have a better economic performance. However, the African region, with its largest number of countries, is a poor performing region. A few of the African countries have high real per capita income in 2009, but the majority is characterized with low levels of income. Furthermore, two of the South Asian countries, Bangladesh and Nepal, and one Latin American country, Haiti are exceptions in their respective regions, sharing low income levels with sub-Saharan African countries in 2009.

The variance of the relative transition parameters consistently increased for the world countries till 2000, but has started to decline in more recent years. This decline may be sourced from Asian and European regions because of decreasing pattern in the variance of their relative transition parameters. An alternative interpretation of these results on world countries can be made through various income categories. The low income cluster has an increasing dispersion of relative transition parameters. But the upper and lower middle income countries have indicated some periods of reduced variance which is also true for the high income countries during the recent decade. This

implies that a further analysis on growth convergence for various sub-periods may furnish some interesting findings.

Finally, the formation of convergence clubs in this analysis is based on real GDP per capita income level in 2009. It is reasonable to believe that the level of income of countries in 2009 may reflect the role of some macroeconomic, structural and institutional variables. A case in point is the 1st club of world countries, in which the member countries have substantial similarities in their recent values for human capital stocks, life expectancy, physical capital stock and quality of institutions. Nevertheless, there are differences exist between some countries such as the lowest value of human capital stock of 6.6 for Thailand compared to the highest value of 12.6 for USA. However, these variables themselves are not the basis of formation of clubs in this analysis which may add an interesting dimension to this study of growth convergence in a future analysis.

Chapter 8

CONCLUSIONS

8.1. INTRODUCTION

The subject of economic growth has been fascinating researchers for both theoretical and empirical contributions. In the context of growth and development, the inter-related issue of *income convergence* or *economic convergence* is also discussed in the literature for substantial period of time. Initial thoughts on income convergence among countries were deliberated in 18th and 19th century. These were followed by a thorough presentation of the concept by Solow (1956) and Swan (1956). Since then, the subject has developed in various formulations together with multiple methodological and econometric applications. However, any empirical analysis, including the one on income convergence, is dependent on availability of data for cross-section of countries over some long time period. Given various databases of world countries, a plausibly long period for the global analysis of income convergence is 1950-2008, which (as mentioned in chapter 1) is also an important time-frame in the economic history of countries.

This study analyzes income convergence among world countries and its various geographic and income categories for the last fifty to sixty years. Together with the analysis of the full world sample, cross-country convergence is studied among four geographic regions, namely, Africa, Asia, Europe and Latin America & Caribbean. The separate analysis for each of the regions is pertinent given their different histories, levels of development and economic performance. Besides this natural classification, income categories of world countries can add an interesting perspective in this analysis on *catching up*. Therefore, income convergence is also examined within the high income, upper middle income, lower middle income and low income categories.

8.2. MAJOR FINDINGS AND POLICY IMPLICATIONS

It is well known that the concept was developed in the backdrop of theory of economic growth and subsequently, is an important component of this theory. In this context, the discussion on the theories of economic growth is presented in the first half of chapter 2. The possibility of income convergence envisaged by the neo classical growth model (NGM) was opposed by the early endogenous growth theories primarily on the basis of increasing returns to scale in production and differences in levels of human capital and technological development of countries. However, later endogenous growth theories supported the catching-up among countries due to technology transfer. Therefore, convergence in total factor productivity (TFP) is rendered as a major potential source of economic convergence by some of endogenous growth theories.

This discussion on theories of economic growth is followed in the thesis by a retrospect on per capita income levels and long run income growth of the world sample and its eight categories in 2nd part of chapter 2. A comparison of income levels in 1950 and 2008 reveals lowest per capita income for Africa which is also characterized with relatively low decade average income growth over these years. A completely opposite case is the Asian region which has attained one of the highest levels of per capita income growth in each decade. As an approximate analysis on income convergence, the income category of each country in 1950 is compared with the respective category in 2008. It is evident that some of the low income and lower middle income countries of 1950 have been able to be part of higher income categories by 2008.

The descriptive analysis set the base for a wide-ranging empirical study of income convergence beginning with the estimation of absolute β and σ convergence in chapter 4. This analysis covers a world sample of 136 countries for the period 1950-2008. Absolute β -convergence is estimated with five-yearly panel data of GDP per capita and GDP per working age person. While, trend regressions are estimated for two measures of dispersion, namely, the coefficient of variation of income and standard deviation of log income, to analyze σ -convergence. There is no evidence of

unconditional β -convergence for the world sample and the African and Latin American regions, but European and Asian countries have the tendency to approach their respective common levels of per capita income in a time span of more than 100 years. Similarly, high and upper middle income countries are converging and there is evidence of absolute income divergence for the low income group. An interesting and novel finding is the evidence of absolute β -convergence for the sample of world countries excluding SSA. These 91 countries are converging towards the identical per capita income level albeit at a very slow pace, requiring about 260 years to reduce half of the gap between the poor and the rich countries.

Results on absolute β -convergence for GDP per working age person are slightly different than those with GDP per capita but, a much greater disagreement is observed in the results for the two measures of σ -convergence. At times, the coefficient of variation indicates σ -convergence while, σ -divergence is reported using the standard deviation of log income for the identical sample. This has an important implication for the relationship between β and σ convergence. It is widely concluded in the earlier convergence empirics that β -convergence is a necessary condition for σ -convergence but not vice versa. Results in chapter 4 indicate that this relationship is only valid with the standard deviation of log income being the measure of σ -convergence. Results of the study indicate that σ -convergence if measured through the coefficient of variation of income is not related to the β -convergence because for some samples, there is evidence of σ -convergence in the absence of β -convergence. This may further imply that the study of β -convergence or *catching-up* is not completely parallel to that of σ -convergence which is based on reduced income dispersion.

It is quite well known in convergence literature that the NGM actually implies a conditional form of β -convergence and not absolute convergence, which has also been analyzed in some cross-country and many inter-country studies. Though, absolute β -convergence can be a useful empirical test for cross-country analysis, conditional β -convergence seems plausible to analyze given various structural, social-economic and demographic variables of countries and their respective differences across them. Chapter

5 furnishes an empirical analysis of conditional β -convergence for the world sample and its various categories. However, the total number in the cross-section and time period is reduced to 98 countries and fifty years (1960-2008) respectively, because of non-availability of some data. Again, both output measures, GDP per capita and GDP per worker are considered in this analysis and the augmented Solow model and Barro growth regression frameworks are applied for estimation.

Referring to the augmented Solow model estimations, the highest rates of conditional β -convergence, among various geographic regions, pertain to the European continent followed by the Latin American & Caribbean and Asian regions respectively. Moreover, lowest rates of convergence are concluded for the African countries. Correspondingly, upper middle and lower middle income countries are converging towards their respective steady states at sizeable rates but not the low income category, which constitutes the largest count of countries. But the low income countries, together with all other categories have a higher income convergence rate in the Barro regression framework than in the augmented Solow model estimations. This implies that besides physical and human capital and population growth, a variety of other factors have important contributions to make in the growth and convergence of countries.

The results on conditional β -convergence contain some unique findings such as different rates of convergence with GDP per worker and GDP per capita in the augmented Solow model estimations for all samples. The income convergence rate is higher than the rate of convergence in GDP per worker for all samples except for the African and low income countries. The convergence in GDP per worker/labour productivity is pertinent from the perspective of economics, but the subject of development emphasizes more on income convergence. This difference, not previously discussed in literature, can be explained by the trend in the workers to population ratio across countries. Thus, the demographic age structure together with the record of population growth has played an important role in income convergence of countries.

Apart from rates of conditional β -convergence, results on the augmented Solow model indicate an interesting and novel finding regarding human capital. Despite its

theoretical importance, studies have often reported a negative and/or insignificant impact of human capital on economic/income growth. A new form of this variable, human capital per person is regressed on income growth and the majority of coefficients are positive and significant. This may be mainly because of a weak relationship between physical capital and human capital per person, which otherwise is considered a major cause for an insignificant impact of human capital on income growth.

Continuing with the discussion on income convergence, the poor evidence of conditional income convergence for the low income group is further investigated in chapter 6. The convergence literature has usually identified initial human capital as being the key in income convergence. But the analysis on low income countries established institutional quality, not the initial human capital, as the critical variable for income convergence of the low income cluster. Results found that only low income countries with a relatively better institutional quality have been able to converge to their respective steady states over the period 1960-2008.

As mentioned above, convergence in factors of production and convergence in TFP are emphasized for economic convergence by the NGM and endogenous growth theories respectively. A study of the sources of convergence in chapter 6, illustrates a sizeable conditional β -convergence in physical capital per worker and TFP for all sample categories. However, human capital per worker is conditionally converging only in Asia and the high income countries; although there is evidence of convergence in human capital stock for all these samples. These results on sources of convergence are consistent with the estimated (also reported in Table 6.4) rates of conditional β -convergence of GDP per worker and income.

One critical aspect in the methodology underlying conditional β -convergence is the assumption of common speeds of convergence across time periods and countries and technological growth rates across countries. Allowing for variability in these coefficients, Phillips and Sul have developed a methodology for the analysis of conditional σ -convergence, also termed as *growth convergence*, also identifies and reports convergence clubs within the particular sample. This methodology was applied

to all nine samples of study. There is no evidence of overall growth convergence in any of the samples, though there are convergence clubs within each group. The number of clubs to an extent seems to depend on the number of countries in each sample, accordingly, the larger number of clubs exists within Latin America & Caribbean and Africa. But this is not totally the whole story because with 19 members each, the Asian and European regions are formed in to 1 and 2 clubs respectively and the world sample itself with 110 countries is divided into six clubs. In contrast, with its 23 countries, Latin America & Caribbean region has 5 clubs. Practically, it is difficult to conclude that clubs with just two or three member countries are real convergence clubs. Alternatively, it can be interpreted that there are weak similarities between countries or just a residual of poor performing countries are being pooled together.

A descriptive analysis of income growth and convergence suggests that there are some low income countries which have remained low income even after 60 years, and these low performing countries largely belong to sub-Saharan Africa (SSA). Much has already been said in the literature about the poor growth performance of SSA countries and plausible policies for enhancing income growth in the region. However, income growth regression, consistent with Barro's Approach, for the African continent indicates that policies directed towards the improvement in health and better institutional quality can enhance the long-run income growth of this region. Similarly, it may also be inferred from our further analysis of the conditional β -convergence of low income countries that at low levels of development, the proper development channel in the form of improving institutional quality has a more important role to play than impacting on the factors of production.

A comparative analysis of conditional β -convergence in GDP per worker and GDP per capita implied that the trend in the workers to population ratio is playing a key role in translating convergence in GDP per worker into income per capita convergence. In this context, the largest difference between these two rates of convergence is observed for the Asian continent which may be indicating that a '*demographic gift*' (positive difference between growth in workers and population growth) is a vital input in the

income growth and convergence of the Asian region, while this factor has been completely absent in the African region thus leading to an opposite effect. Therefore, population growth control programs and resultant positive difference between workers' growth and population growth can help increase per capita income growth in these countries.

The analysis on growth convergence and convergence clubs specified different number of clubs with in the world sample and within its various geographic groups. Interestingly, the single club for European countries may suggest that the strongest clubs are when there is effective regional collaboration and such collaboration is 'working' for the club membership. Such regional collaboration can be observed to an extent within the convergence clubs for Africa and Latin America and the Caribbean. In the African continent, many (9 out of 13 in the 3rd club) member countries of ECOWAS are together in one club, while, 4 of the 5 MERCOSUR countries are part of 2nd convergence club in the Latin American sample. This may imply that regional integration can be helpful for income convergence among countries.

8.3. APPROACHES OF CONVERGENCE IN A COMPARATIVE PERSPECTIVE

The study has utilized four different notions or concepts of income convergence, each having a distinct methodology. After a comprehensive analysis on all these approaches using nine samples, the obvious question is which of these notions best describes the phenomenon of income convergence as it is observed in practice? The answer to this question is not straight forward because each approach is based on some simplifications and thus has its advantages and disadvantages. In other words, not one approach is complete in itself to analyze income convergence among countries. Because, as mentioned above, the application of each of the concepts has resulted in some pertinent findings and conclusions. Each has helped further our knowledge. The absolute β -convergence can be regarded as a strong criterion of convergence in which a poor

country is supposed to attain the per capita income level of a rich country. Though this seems implausible for a broad sample of world countries, some regions have indicated positive evidence on absolute income convergence.

In contrast, conditional β -convergence takes into account the country specific characteristics and can help identify some important control variables for income convergence. The varying rates of income convergence for GDP per worker and GDP per capita are identified utilizing this approach. In contrast to conditional β -convergence, the latest approach of Phillips and Sul takes into account variable speeds of convergence and technological growth rates. However, it is a kind of trend regression of cross-sectional variance of countries which is also related to the analysis of absolute σ -convergence. Those results with the standard deviation of log income in chapter 4 are almost similar in conclusions with the results of the Phillips and Sul approach, although that is based on *time-varying factor loading coefficient* (it is worth noting that this dispersion is also based on log of income). However, the Phillips and Sul approach of convergence does not utilize the full time-period of data rather discards a fraction of it, which can have a critical role in results and conclusions. On the other hand, the other three notions of income convergence make full use of the available data for estimations.

Another important question relates to *club convergence* because some of the endogenous growth theories have asserted multiple equilibria and convergence clubs of countries. But if conditional β -convergence entails convergence towards respective steady states of countries, then in a way it implies multiple equilibria. Alternatively, if the phenomenon of club convergence refers to conditional convergence within a more similar group of countries, then conditional β -convergence within eight samples, Africa, Asia, Europe, Latin America and the Caribbean, high income, upper middle income, lower middle income and low income of this study can be regarded as evidence of convergence clubs. In that case one observation is clear, that rates of convergence within a specific region are higher than the respective coefficient for the full world sample in almost all results. This may imply that club convergence seems a narrow form of conditional convergence and there may not be any real difference between the two (as

some studies have already argued). Putting in alternatively, global conditional convergence can be regarded as a farthest target beyond club convergence. Moreover in the context of club convergence, absolute, not conditional, form of β -convergence may be more pertinent to analyze within a relatively similar group of countries (with either geographic or economic similarity). It was the absolute convergence that was actually considered by Baumol (1986), who was the first one to use the concept of convergence clubs. Thus this almost brings us full circle.

8.4. LIMITATIONS OF THE STUDY AND FUTURE RESEARCH

The study of the sources of convergence analyzes conditional β -convergence of each input. However, all the convergence rates are estimated in separate regressions and with no constraints and without the inclusion of other control variables. Thus, it cannot be a convergence accounting exercise linking the individual convergence rates for each input to the corresponding convergence figure for the output per worker. Therefore, one of the limitations of study is that there appears to be no accounting relationship between sources of convergence and convergence in output per worker, which needs to be established in further research. Moreover, other socio-economic variables such as human capital, physical capital and TFP should be included in analyzing the sources of convergence.

The thesis is based on an analysis of income convergence for the full study period, but at times graphical illustrations, particularly in chapter 7, have indicated both convergence and divergence over some sub periods. Similarly, income growth performances of some regions are not uniform over the whole period, rather, some decades have higher average income growth than otherwise [see chapter 2]. Therefore, the possibility of sub-periods of convergence and divergence in various samples needs to be tested. This raises the possibility that convergence, if it exists, is not a smooth continuous process. In addition, although, Phillips and Sul have considered variable speeds of convergence across cross-sections and time periods, it would be interesting to

consider the speed of convergence as a function of certain determining factors and thence to develop a method to analyze the determinants of the speed of convergence.

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